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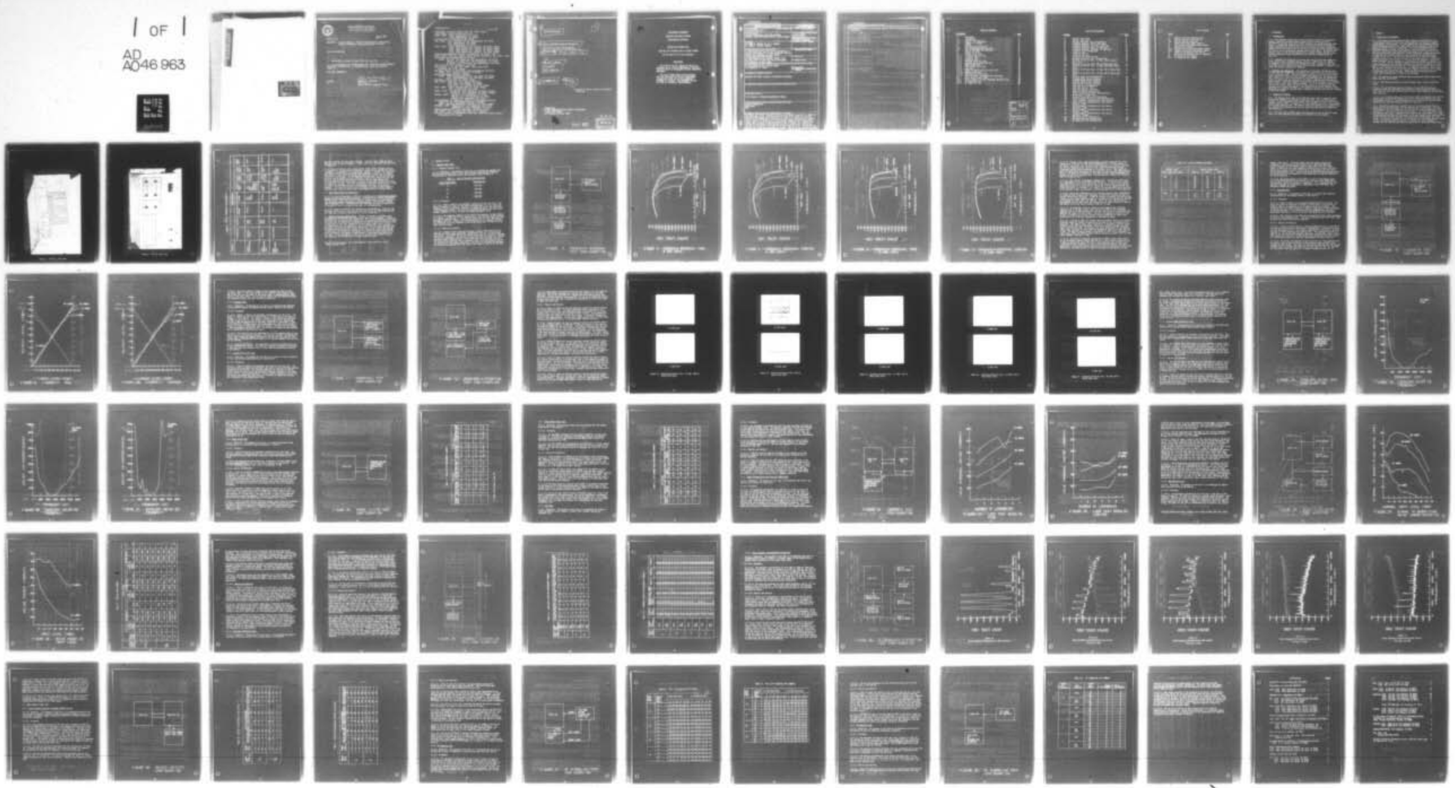

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INTERIM REPORT. Feb - Jul 77

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Testing of the ULM-101 loop multiplexer was initiated to establish a data base and assessment of the continuous variable slope delta (CVSD) and log CVSD modulation techniques and to evaluate its ability to interface with existing signals typical of those in use in the Defense Communications System (DCS). Twelve tests of voice channel performance were conducted and in general the minimum DCS performance specifications for voice channels were met by the ULM-101 when operating at 32 KBPS and 64 KBPS sampling rates. Performance was marginal at 16 KBPS and unsuitable at 8 KBPS. Ability of the ULM-101 to (over)

**Interface with VFCT, SF signalling and MF signalling equipment was evaluated to be marginal.

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1. BACKGROUND

1.1 Introduction

1.1.1 This document reports the results of tests performed on the General Dynamics Universal Loop Multiplexer, Model ULM-101, which utilizes a continuously variable slope delta (CVSD) technique for encoding analog input signals. The US Army Communications-Electronics Engineering Installation Agency (USACEEIA) was assigned the task of evaluating the basic performance capabilities of the ULM-101 and its ability to interface analog signals typical of those in use in the Defense Communications System (DCS). The ULM-101 was tested as part of the US Army Communications Command (USACC) Digital Transmission Evaluation Project (DTEP) during the period of February 1977 to July 1977.

1.1.2 USACEEIA was authorized to perform this mission by US Army Communications Systems Agency (USACSA) message, CCM-SP-C, 292035Z Nov 75. USACSA, Ft Monmouth, NJ is responsible for managing the DTEP. Conduct of the tests was tasked to the US Army Electronics Proving Ground (USAEPG), Ft Huachuca, AZ, under the technical guidance of USACEEIA.

1.2 General Test Objectives. The evaluation of the Model ULM-101 has been divided into four categories to establish the capabilities of the multiplexer in four different areas. The first category consists of twelve voice channel tests conducted on the unit using standard instrumentation. The second category consists of a voice intelligibility test performed with the multiplexer which was coordinated and analyzed by the Defense Communications Engineering Center (DCEC). The third category involves the use of the ULM-101 to interface with various typical quasi-analog equipment. The final category consists of various tests which define the level of performance of the multiplexer when operating in an error environment. This report discusses the results of tests conducted in categories one and three. Categories two and four will be included in the final report.

1.3 Summary of Findings

1.3.1 The channel level tests of the ULM-101 reveal that it generally meets minimum DCA standards (as defined in DCAC 300-175-9, Table II, DCS Technical Schedule Circuit Parameters) for channel level equipment at the 32 and 64 kbps channel sampling rates, is marginal at 16 kbps sampling rate and is unacceptable at an 8 kbps sampling rate. The ULM-101 would be unuseable at any channel rate as a medium of transmission for circuits requiring high quality transmission characteristics.

1.3.2 The quasi-analog signal tests conducted thus far on the ULM-101 reveal that it is only marginally acceptable as a medium for these signals.

2. GENERAL

2.1 Description of Equipment

2.1.1 The General Dynamics Model ULM-101 Universal Loop Multiplexer uses a continuously variable slope delta (CVSD) modulation algorithm to encode analog channel input signals. In delta modulation, the difference between the instantaneous value of the input signal and the quantized value at the previous sampling instant is quantized. It is not the magnitude of the difference which is conded, but the sign; if the difference is positive a pulse is transmitted, causing the quantized value of the signal to rise by one quantizing unit in the receiver. If the difference is negative no pulse is sent out; the receiver reacts to this by making the quantized signal decrease by one unit. Since no more than one pulse is sent out in every sampling interval, the bit rate is equal to the sampling rate. In CVSD, the output developed by the receiver is a function of the number of successive "1's" or "0's". Up to a maximum of three successive pulses, the level of the signal reproduced by the receiver increases in a positive direction in increments of increasing size for each "1". A succession of "zeros", up to a maximum of three, produces the same effect in a negative direction. This allows the CVSD to accurately encode and reproduce signals with high rates of change of amplitude with respect to time. After the fourth successive "one" or "zero", the increment size is fixed at the maximum.

2.1.2 The ULM-101 has three different switch-selectable channel input modes: CVSD, log CVSD, and digital.

2.1.2.1 The CVSD mode encodes an analog channel input signal as described above.

2.1.2.2 The log CVSD mode operates similarly to the CVSD with the one difference, that the granularity (the smallest voltage quantizing level) is finer than for CVSD, thus allowing the low level input signals to be reproduced more accurately.

2.1.2.3 In the digital mode, the CVSD coding circuit is bypassed and a digital input signal at the proper channel rate can be introduced directly into the multiplexing circuitry. In this manner, any mix of up to four digital and/or analog signals can be multiplexed together in the unit.

2.1.3 The ULM-101 operates at channel rates of 8, 16, 32, and 64 kbps and group rates of 128, 256, 288, 512, and 576 kbps and at 1.544 mbps. The group rates between 128 and 576 kbps are available on the "radio" connectors of the multiplexer in the form of NRZ and clock signals. The 1.544 mbps rate is only available on the "cable" connectors of the ULM-101 as a RZ bi-polar (T1) signal. The multiplexer has four active channels, with each channel input card providing switch selection between log CVSD, CVSD and digital processing of the input signal. Circuitry is provided in the multiplexer to create dummy channel signals so that the simulated channel capacity of the ULM-101 varies between 7 [illegible] channels and 192 channels depending on combination of group and channel rates

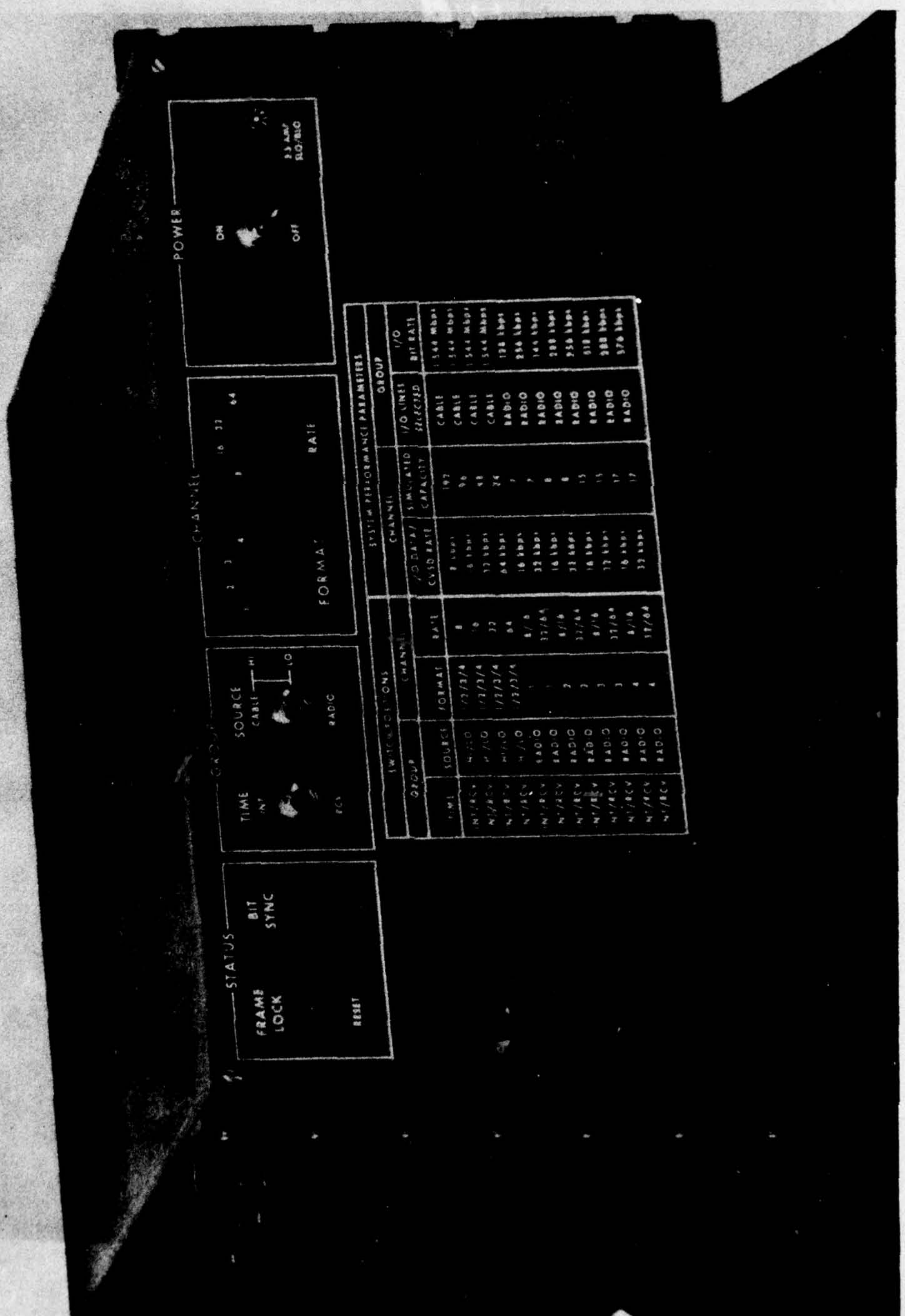


Figure 1. ULM-101, Front View

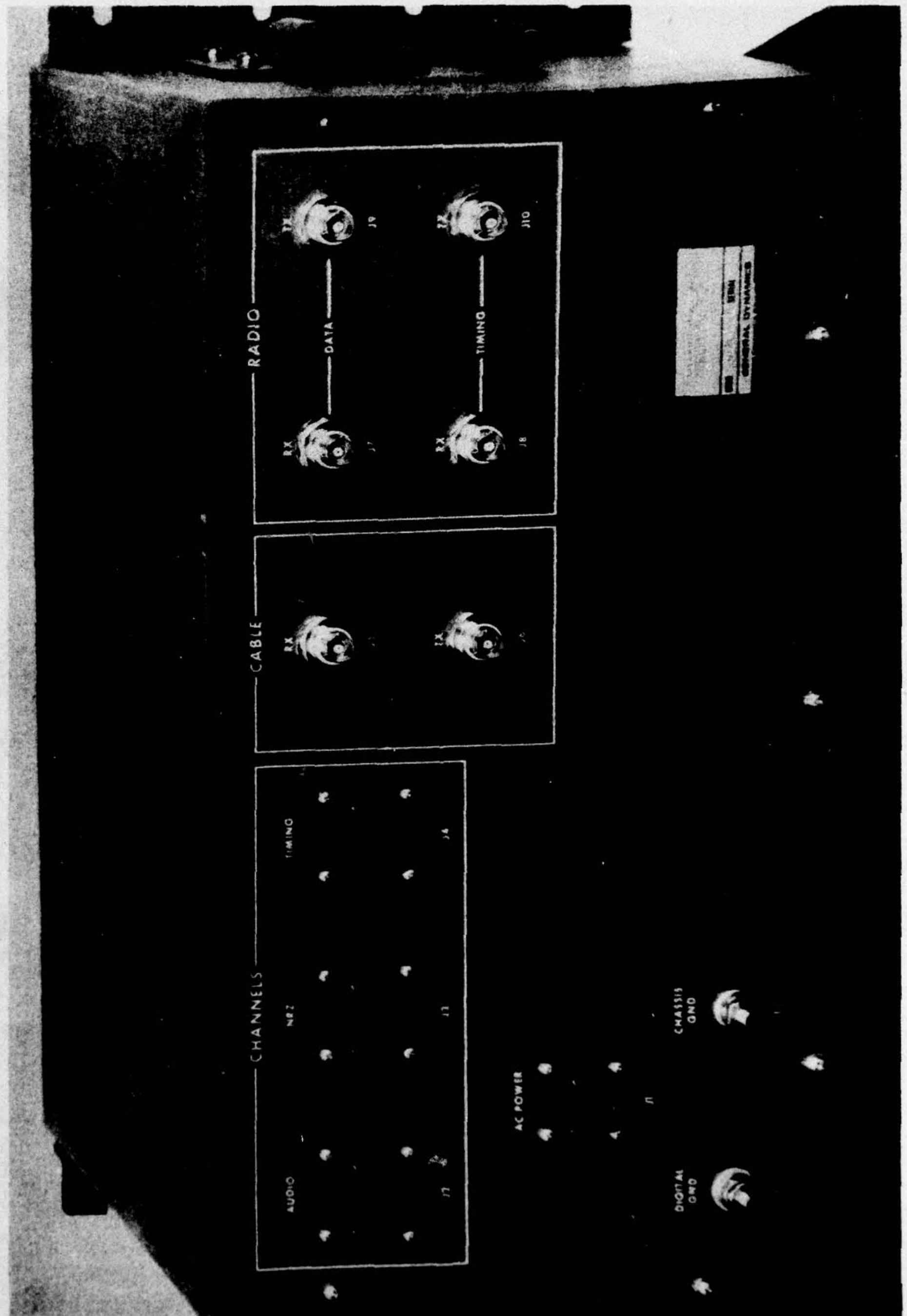


Figure 2. ULM-101, Back View

Table 1. ULM-101 Interface Characteristics

FUNCTION	CHARACTERISTIC							
	Termination	Impedance	Longitudinal Balance	Transmission Format	Transmission Rate	Input Signal Level	Output Signal Level	Output Drive
CHANNEL INPUT/OUTPUT	Balanced 4-Wire	600Ω ±10%	>40 dB	NRZ and Timing	16/32/64 kbps digital/300-3300 Hz Voice	0.15v p-p to 3v p-p	3v p-p ±10%	4 Ma
GROUP INPUT/OUTPUT CABLE	Balanced	100Ω 100Ω ±10%	>40 dB	Bipolar	1.544 Mbps	0.15v p-p to 6v p-p	6v p-p ±10%	3.2 Ma
GROUP INPUT/OUTPUT RADIO	Single Ended	78Ω ±10%	—	NRZ and Timing	128, 144, 256, 288, 512, 576 kbps	TTL Compatible	TTL Compatible	—

that are selected via front panel switches. Figures 1 and 2 show the front and back views of the multiplexer. Table 1 lists the interface characteristics of the unit.

2.1.4 The data from the four active and the proper number of dummy channels is formatted in the multiplexer transmitter section of the ULM-101 and framing information, consisting of a pseudo random sequence, is added. The composite data stream is then converted to NRZ and timing for a radio link, or bipolar format for a cable link. In the demultiplexer/receiver, the bit synchronizer extracts timing and NRZ from the 1.544 mbps bipolar data stream and then this data, or alternatively NRZ data and timing at the six lower group rates directly from the radio link input, is routed to the frame synchronizer within the multiplex receiver. The frame synchronizer determines the start of a frame and causes the multiplex receiver to demultiplex the data in the correct sequence. The data for the four active channels is routed to the respective channel output cards for conversion to the proper digital or analog format.

2.2 Test Methodology and Limitations

2.2.1 The detailed procedures contained in the test plan "Test Plan for General Dynamics Analog/Digital CVSD Multiplexer" USACEEIA Publication No. CCC-TED-76 TR-226, October 1976, were based on standard methods such as are documented in "*DCS Technical Control Procedures, Test Description*", DCAC 310-70-1, Supplement 1, November 1972. The procedures were modified for specific application to the ULM-101 and to incorporate new types of instrumentation.

2.2.2 No unusual limitations were encountered during testing. Limits on the data were established by the accuracy and stability of the test equipment and all items were constantly monitored for correct calibration.[1]

2.3 ULM-101 Equipment Modification. Efforts to perform an envelope delay measurement on the ULM-101 were unsuccessful when first attempted. A check of waveforms with an oscilloscope revealed that the amplitude modulated test signal which had been introduced by the measuring set had its negative portion clipped at the output of the loop integrator on the channel output card. A 0.047 microfarad capacitor was inserted in the line between the loop integrator output and driver input on each channel output card. This allowed the amplitude modulated envelope delay test signal to pass through the output undisturbed. It did affect the response of the output circuitry with signals below 500 Hz being attenuated with respect to the response of the unmodified channel output card. A 5 db degradation at 200 Hz, was noted on the modified circuit. This capacitor was in place for all tests except as noted.

[1] Calibration Requirements for the Maintenance of Army Materials, DA TB 43180, December 1975.

3. DETAILS OF TEST

3.1 Channel Level Tests

3.1.1 Frequency Response Test

3.1.1.1 Objective. The purpose of this test is to define the passband and out-of-band characteristics of the ULM-101 analog input/output circuitry. The multiplex is specified to have the passbands listed in Table II.

TABLE II - ULM-101 Passband Specifications

Channel Rate (KBPS)	Passband (Hz)
8	300-1500
16	300-2000
32	300-3800
64	300-3800

3.1.1.2 Procedure

3.1.1.2.1 Figure 3 depicts the equipment configuration for this test. The output frequency and level of the audio oscillator were first set using the frequency selective voltmeter, which has a regenerated output for connection to the frequency counter. The frequency selective voltmeter used had a measurement bandwidth of 10 Hz in order to minimize detection noise.

3.1.1.2.2 The frequency response of the ULM-101 was measured at input levels of 0 dBm and -13 dBm, and for all combinations of multiplexer coding technique and channel sampling rates. A multiplexer group rate of 1.544 Mbps was used throughout the test. Testing with each combination of multiplexer settings was continued up to the frequency at which the output was a minimum of 30 dB lower than the input.

3.1.1.3 Results and Analysis

3.1.1.3.1 Figures 4 and 5 show the frequency response characteristics for CVSD and log CVSD coding techniques, respectively, and for a 0 dBm channel input level. The curves for 16, 32, and 64 kbps rates are virtually unchanged for the two techniques. The curves of 8 kbps show that log CVSD has a sharper bandwidth cutoff characteristic. The curves show that the lower 3 dB point for both coding techniques and all sampling rates is at approximately 350 Hz. The frequency for the upper 3 dB point is the same for both coding techniques, but varies with sampling rate from 1000 Hz for 8 kbps to 1800 Hz for 64 kbps.

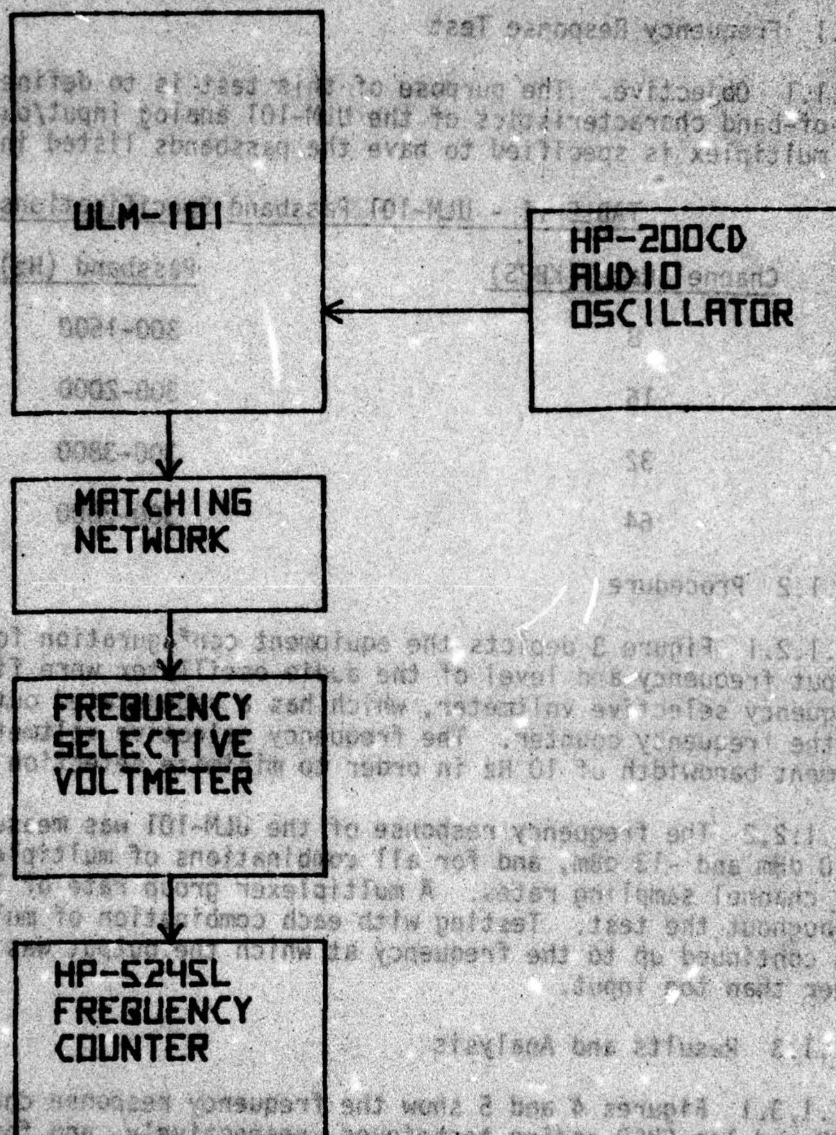


FIGURE 3. FREQUENCY RESPONSE TEST CONFIGURATION

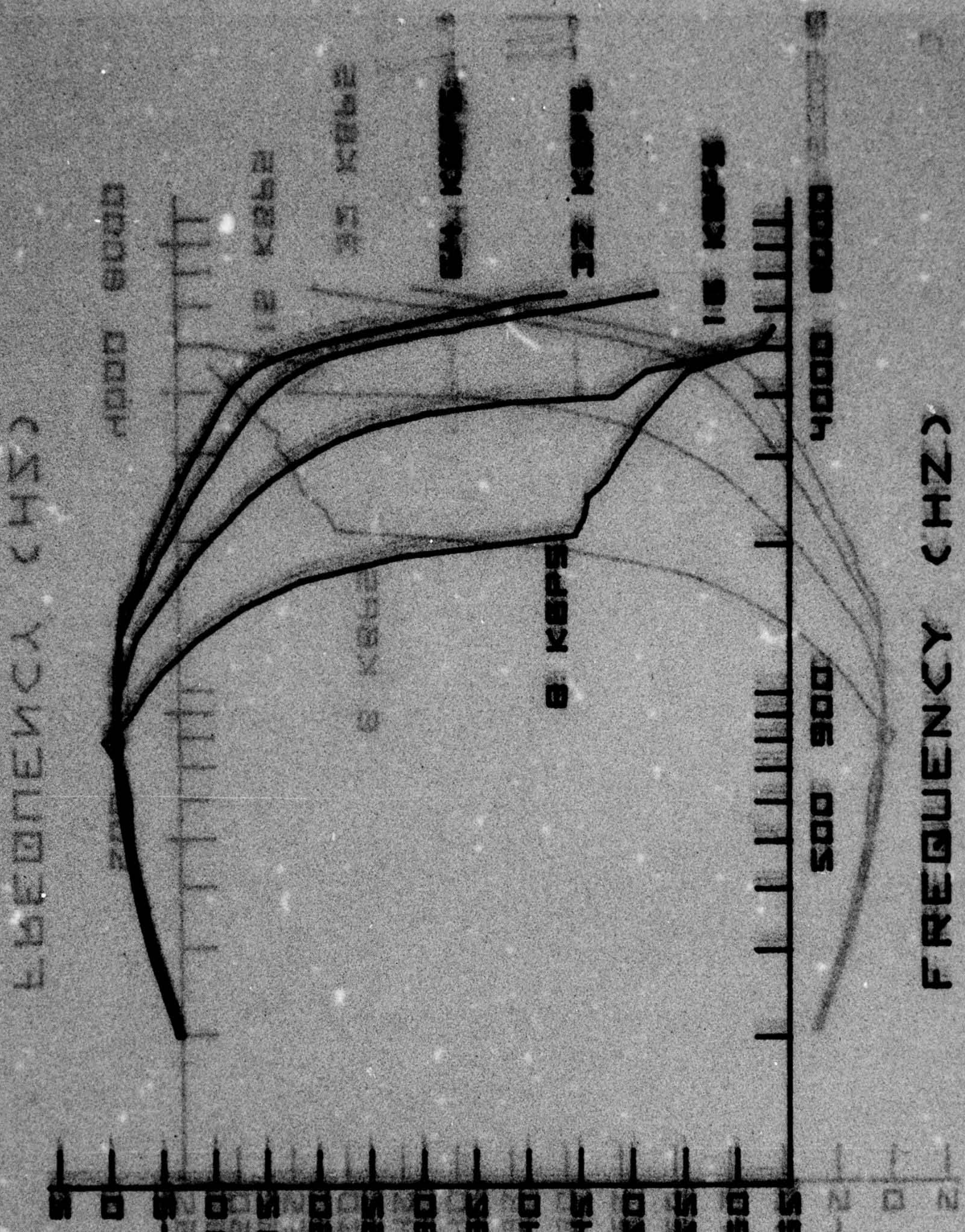


FIGURE 4. FREQUENCY RESPONSE, CVSD
0 DBM INPUT

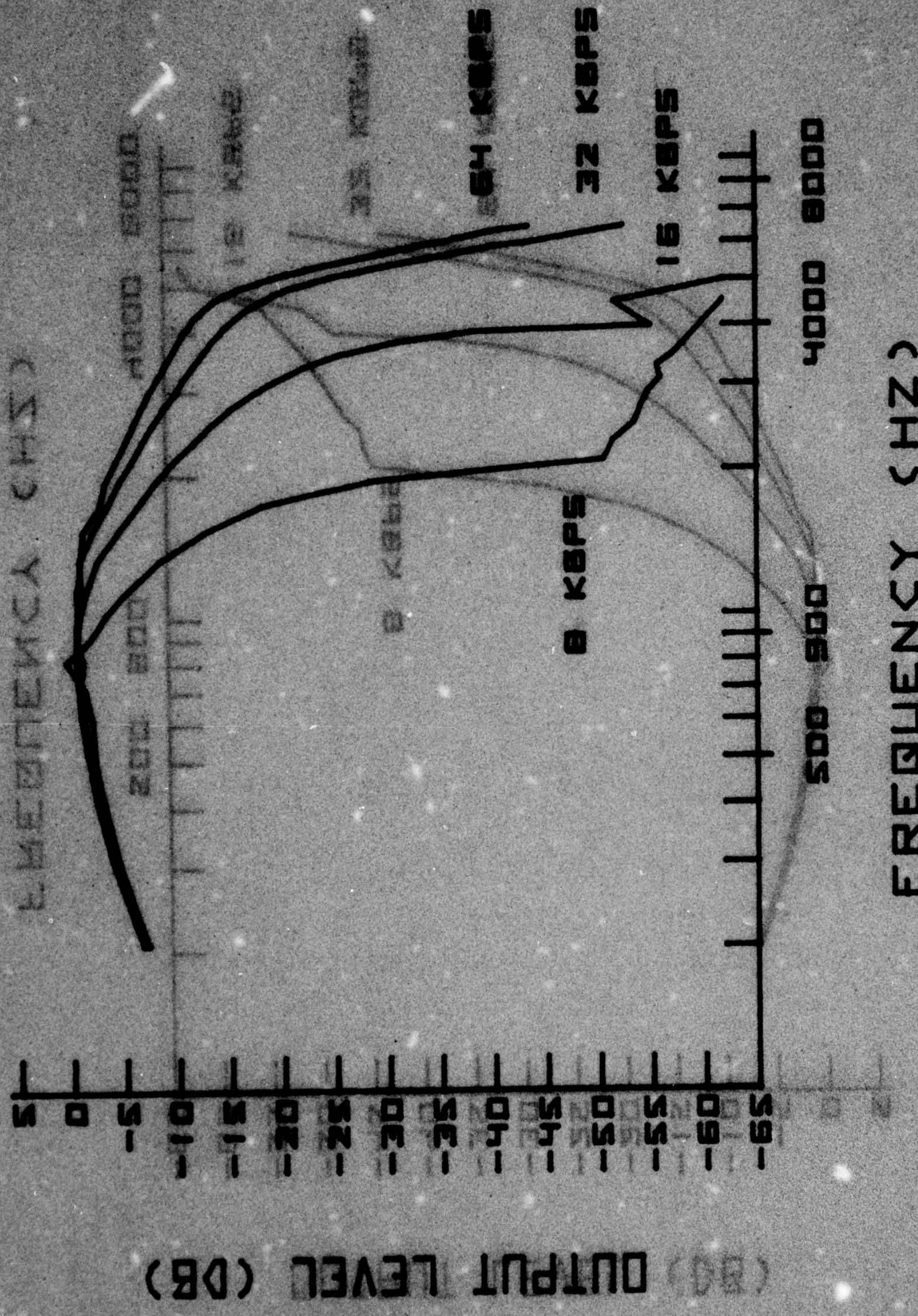


FIGURE 5. FREQUENCY RESPONSE, LOG(VSD)
0 DBM INPUT

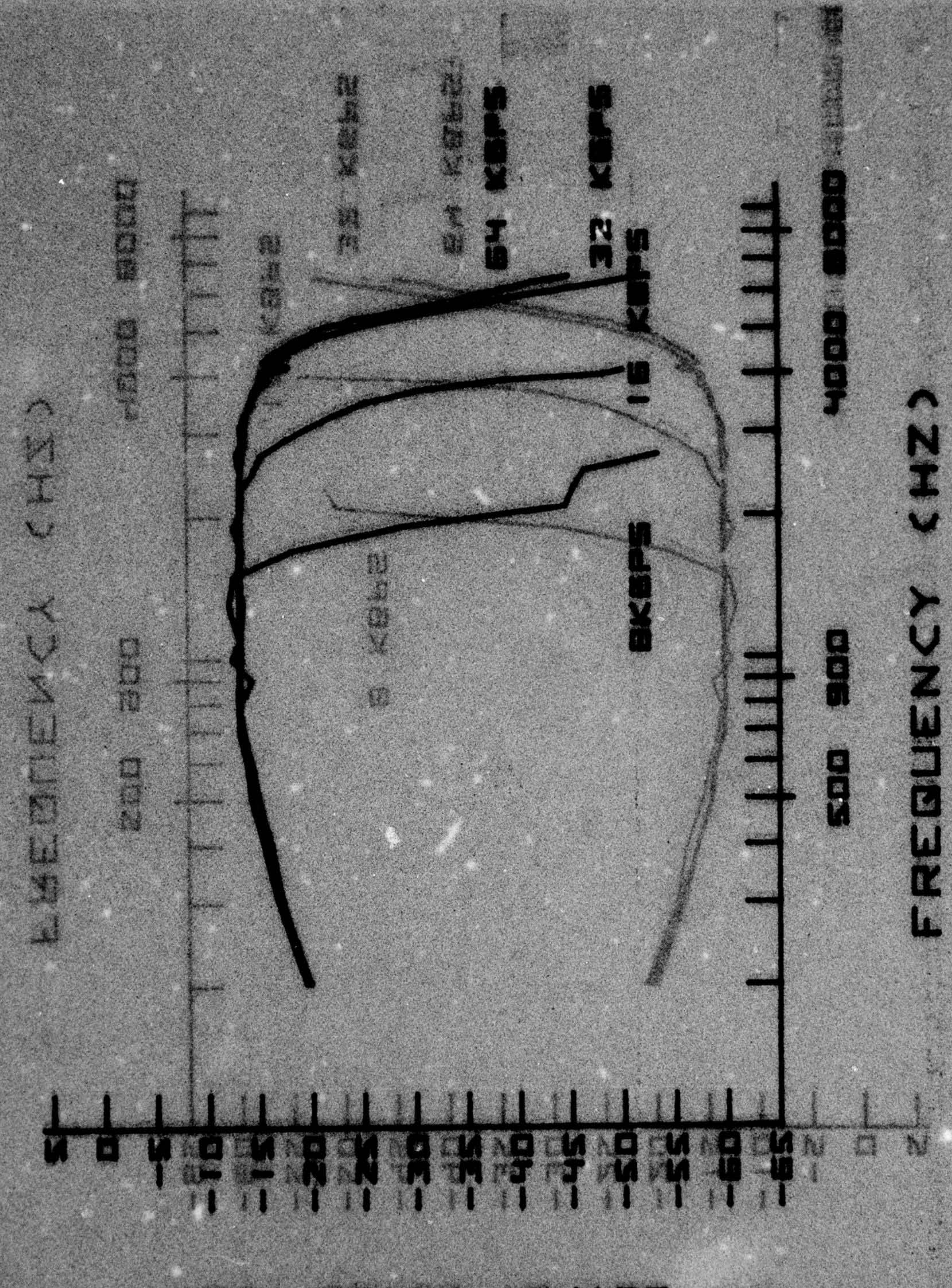


FIGURE 6. FREQUENCY RESPONSE, CVSD
-10 DBM INPUT

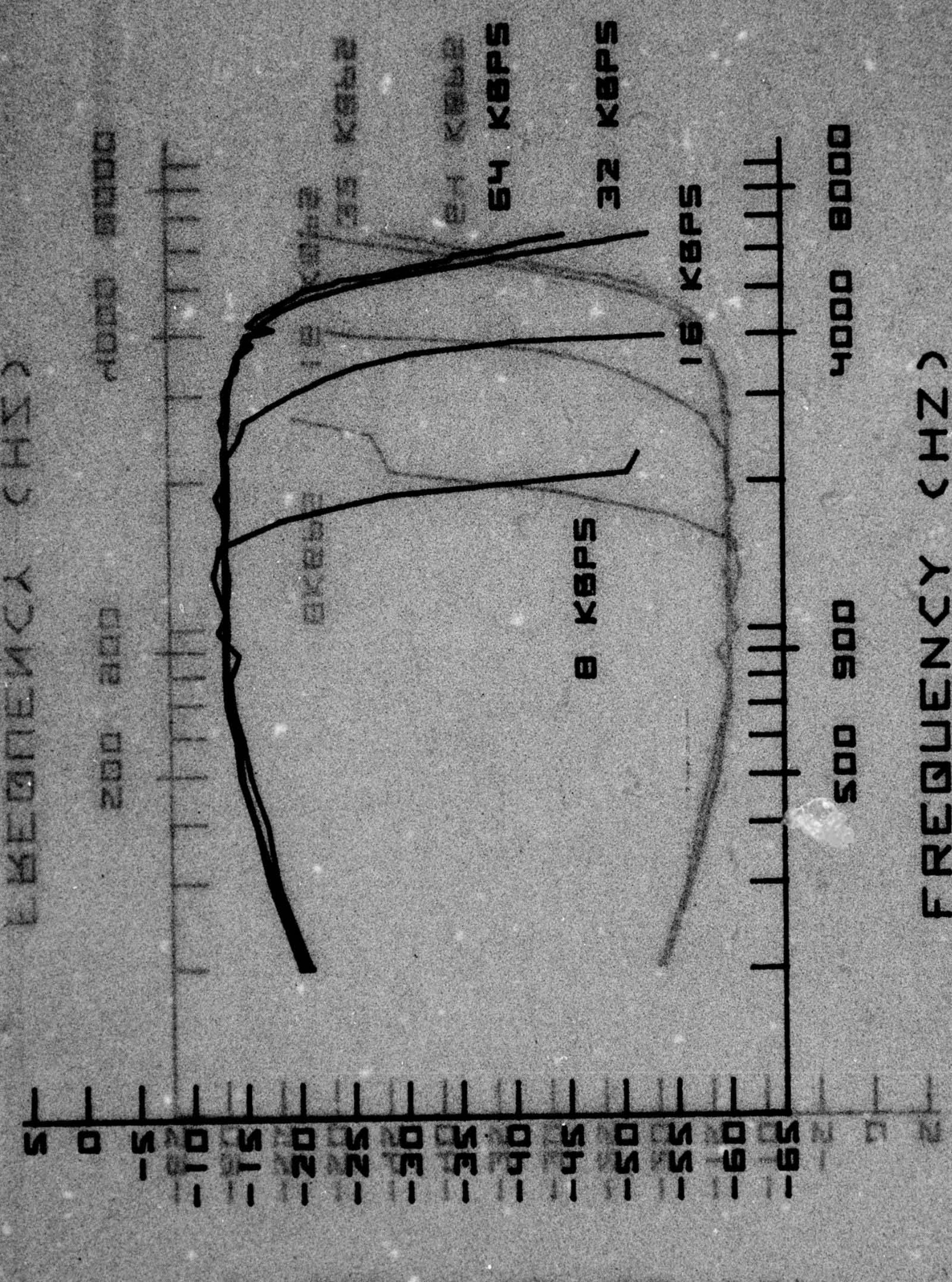


FIGURE 7, FREQUENCY RESPONSE, LOGCVSD
-13 DBM INPUT

3.1.1.3.2 Figures 6 and 7 show the frequency response characteristics for, respectively, CVSD and log CVSD coding techniques for a -13 dBm channel input level. The results for the two coding techniques are virtually identical for all four sampling rates, with only the 8 kbps rate showing a slight divergence between coding techniques at low output levels. The lower 3 dB point for both coding techniques and all sampling rates is again approximately 350 Hz. The upper 3 dB frequency is the same for both coding techniques but varies once more with sampling rate, from approximately 1600 Hz for 8 kbps to 4100 for 32 and 64 kbps.

3.1.1.3.3 The increase in frequency response with a decrease in input level is a consequence of the delta modulation technique. If one defines a modulation index as the ratio of the derivative of the input signal to the maximum permissible value of this derivative, the system is fully modulated when the signal derivative is a maximum. As a result, the maximum permissible amplitude of a sinusoidal signal to be coded is inversely proportional to the frequency.

3.1.1.3.4 During the performance of the frequency response test, subharmonics of a 6000 Hz test frequency were observed, so additional testing was done to further define these responses. A 6000 Hz tone was introduced into the channel input at various levels between 0 dBm and -13 dBm and the response was measured at frequences of 2000, 4000, and 6000 Hz. Table III lists the results of measurements made at 2000, 4000, and 6000 Hz with an input stimulus of 6000 Hz and 2000 Hz at various levels between 0 dBm and -13 dBm.

3.1.1.3.5 The responses listed in Table III were observed for a ULM-101 sampling rate of 64 kbps and for both CVSD and log CVSD coding techniques. A sampling rate of 32 kbps produced very similar results while no responses were observed for rates of 8 and 16 kbps. The lack of response at rates of 8 and 16 kbps is probably due to much narrower channel bandwidths at these rates which result in a very high attenuation to the 6000 Hz signal.

3.1.1.3.6 A review of Table III reveals that the channel reacts in a radically different manner to signals in-band and out-of-band as far as harmonics are concerned. The 2000 Hz input signal resulted in a reasonably constant second harmonic signal level and relatively little third harmonic content once the signal falls below 0 dBm. By contrast, the third sub-harmonic of the 6000 Hz input signal is higher in level than the fundamental down to an input level of -8 dBm. The 2000 Hz product generally decreases in level with a decrease in input level, while the 6000 Hz signal remains constant in output level at input levels between 0 dBm and -10 dBm.

3.1.1.3.7 The spurious responses observed for a 6000 Hz input signal could not be thoroughly checked through the ULM-101 circuitry because extensive use is made of operational amplifiers and no instrumentation was available with a high enough input impedance to avoid loading down the outputs from these amplifiers. The spurious signals apparently originate from the circuitry which performs the analog-to-digital or digital-to-analog transformations of the

TABLE III. ULM-101 HARMONIC RESPONSES

Channel Input		Channel Output (dBm)		
Freq (Hz)	Level (dBm)	2000 Hz	4000 Hz	6000 Hz
6000	0	-28	-61	-34
	-3	-30.5	-45	-34
	-5	-33	-42	-34
	-8	-28	-45	-34
	-10	-43	-40	-34
	-11	-48	-45	-36
	-13	-60	-53	-97.5
2000	0	- 3.5	-40.5	-41
	-10	-10	-37	>-60
	-13	-13.3	-45	>-60

channel input signal. The anlog signal from the channel output card originates in the analog decision circuitry as an amplitude modulated digital waveform (at the channel sampling rate) from which the analog signal is derived by the loop integrator, amplified by a driver, and band-limited by an output low pass filter with an 18 dB/octave roll-off starting at approximately 5 KHz. The processing and band-limiting characteristics of the circuitry are not conducive to the generation of spurious signals at the levels observed.

3.1.1.3.8 The analog signal at the "Audio In" port of the channel input card is amplified and then band-limited by a low pass filter comprised of an operational amplifier and passive components. It is suspected that the spurious responses are generated as resonances in the filter which then propagate through the system.

3.1.2 Linearity Test

3.1.2.1 Objective. The purpose of this test is to define the linearity characteristics of the analog channels of the ULM-101.

3.1.2.2 Procedure.

3.1.2.2.1 Figure 8 depicts the equipment configuration for this test. The audio oscillator was adjusted to provide an input level to the ULM-101 of 0 dBm at 1000 Hz, as measured by the frequency selective voltmeter. The attenuator was then used to reduce the signal at the input to the multiplexer to the desired level. The frequency selective voltmeter was used with a measurement bandwidth of 10 Hz to minimize the amount of noise detected.

3.1.2.2.2 The linearity of the ULM-101 was measured for both coding techniques and for all four sampling rates. Testing was continued down to an input level at which non-linear operation was apparent.

3.1.2.3 Results and Analysis.

3.1.2.3.1 Figures 9 and 10 show the linearity characteristics of the ULM-101 for CVSD and log CVSD coding techniques, respectively. A straight line equation was developed using a least squares technique for the data for each combination of coding technique and sampling rate. The computed lines for log CVSD for 16, 32, and 64 kbps sampling rates were slightly more linear than for CVSD coding; the slope for log CVSD varied by no more than 0.5% from a value of 1 while the variation for CVSD was approximately 5% from a value of 1.

3.1.2.3.2 The obvious nonlinearity of the curves for an 8 kbps sampling rate on figures 9 and 10 were reflected in the calculated best straight lines through the data points. The slope for CVSD coding technique was .910 and the standard error of estimate for any point on this line was .74. For log CVSD the calculated slope was .953 with a standard estimate of error of .77.

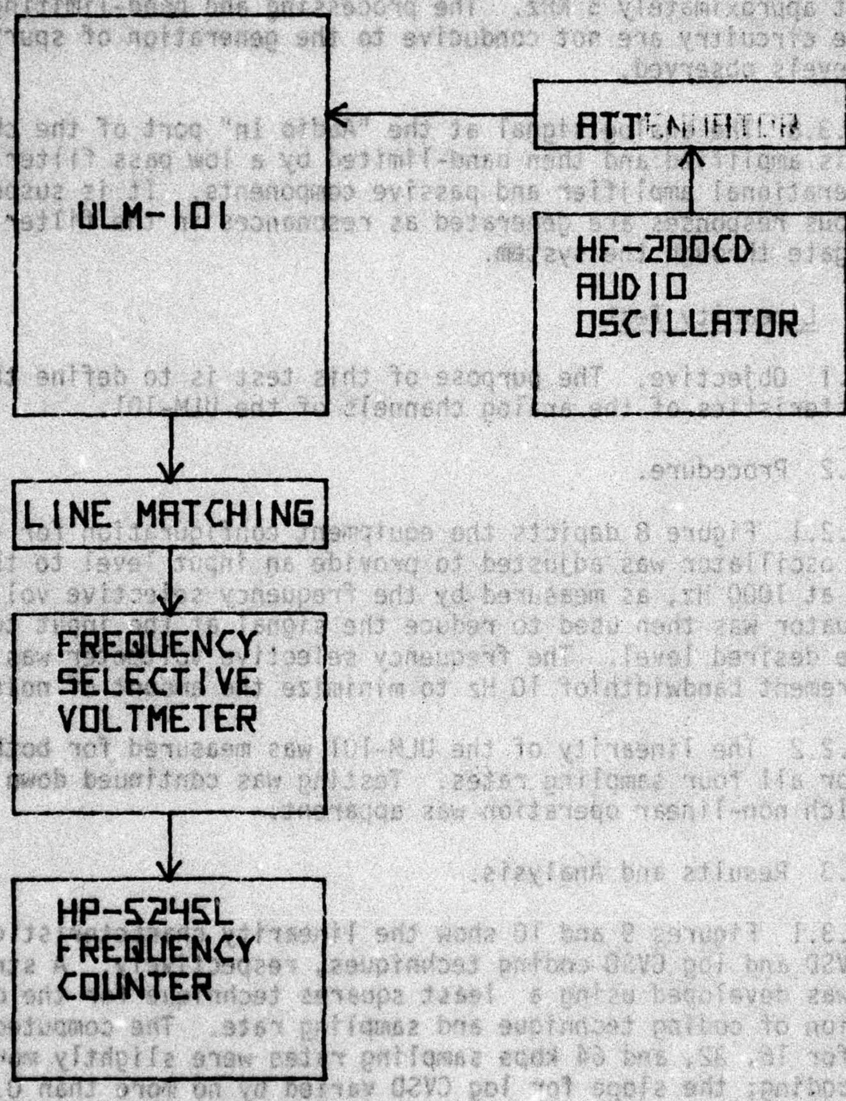


FIGURE 8. LINEARITY TEST CONFIGURATION

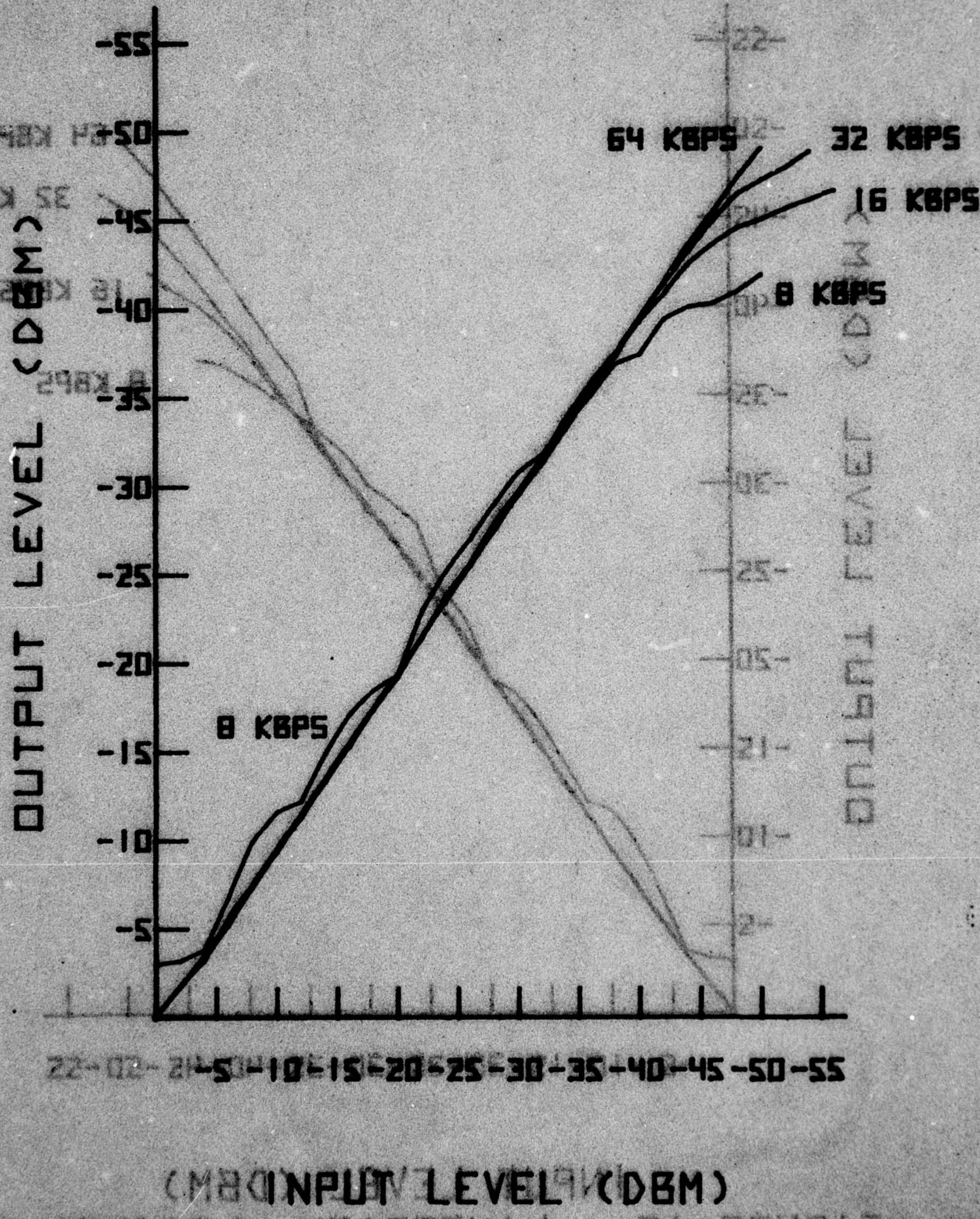


FIGURE 9. LINEARITY (VSD)

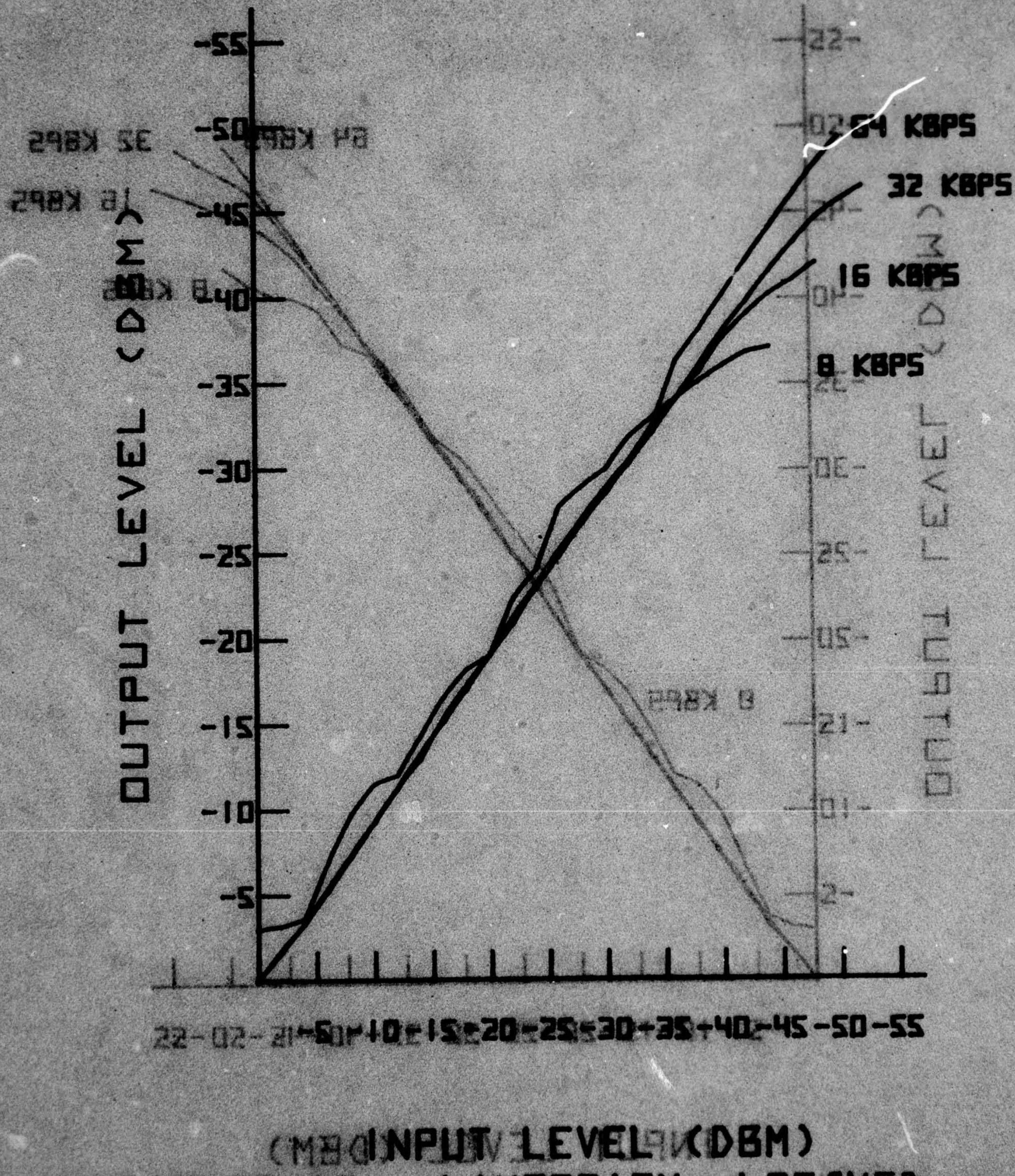


FIGURE 10. LINEARITY LOG(VSD)

3.1.2.3.3 The curves shown in figures 9 and 10 become nonlinear at very low input levels -- less than -40 dBm for all sampling rates except 8 kbps -- due to the fact that the level of the input signal is approaching the granularity of the delta coder. For the type of signals that the CVSD multiplexer will normally process, this will create no difficulty.

3.1.3 Crosstalk Test

3.1.3.1 Objective. The purpose of this test is to determine the crosstalk levels observed between two adjacent analog channel inputs on the ULM-101.

3.1.3.2 Procedure.

3.1.3.2.1 Figure 11 depicts the equipment configuration for this test. The output of TIMS #1 was set to a 1000 Hz tone at a 0 dBm level at the input to channel 1 of the ULM-101. The channel 2 output of the ULM-101 was monitored by TIMS #2 set to make an idle channel noise measurement (this measurement provides a 600 ohm termination on the cable connected to the channel 2 input of the ULM-101). An idle channel noise measurement was made at the channel 2 output first with a 0 dBm signal input to channel 1 and then with the channel 1 input terminated in a 600 ohm load. The difference between the two readings was an indication of the crosstalk level.

3.1.3.2.2 The crosstalk test was performed for all four sampling rates of the ULM-101 and for both coding techniques. The test was initially performed with direct cable connections between the ULM-101 and the TIMS test sets and then redone using a standard audio patch panel as an interface between the test sets and the ULM-101.

3.1.3.3 Results and Analysis. No discernable crosstalk was observed for any of the configurations tested. This does not indicate an absence of crosstalk; it does show that the crosstalk level is less than the quantizing distortion of the ULM-101.

3.1.4 Waveform Distortion Test.

3.1.4.1 Objective. The purpose of this test is to obtain a visual indication of the slope overload characteristics of the ULM-101.

3.1.4.2 Procedure.

3.1.4.2.1 Figure 12 depicts the equipment configuration for this test. The matching network and matching transformer were used to provide 600 ohm balanced interfaces to the ULM-101. The function generator was adjusted to provide several different input levels and different frequency waveforms at the input to the ULM-101. The output waveforms from the function generator and from the ULM-101 were displayed on a dual-trace oscilloscope for comparison purposes and photographs of the displays were made.

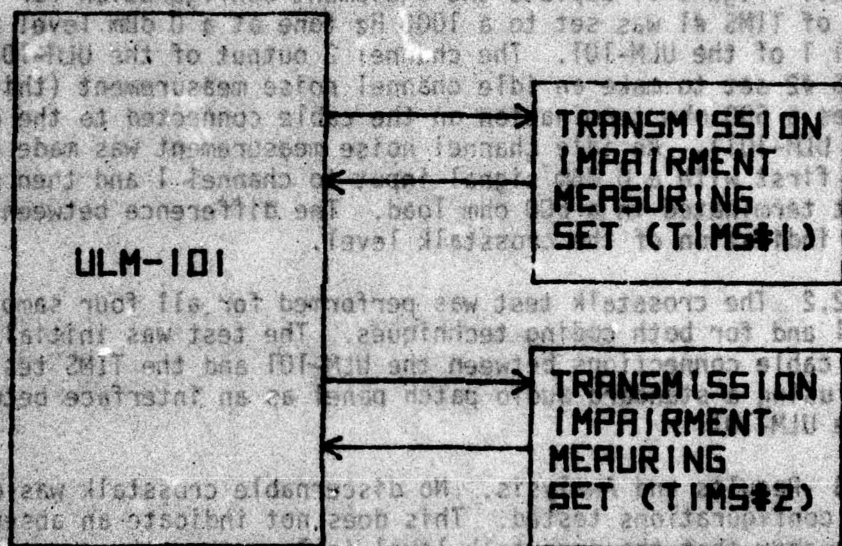


FIGURE 11. CROSSTALK TEST CONFIGURATION

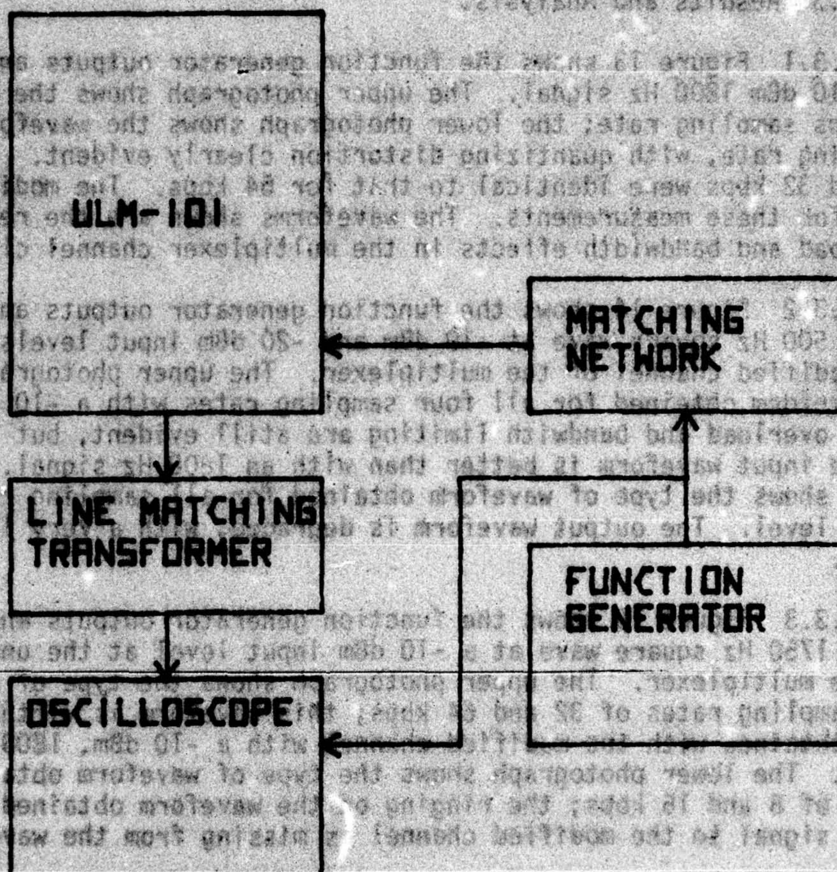


FIGURE 12. WAVEFORM DISTORTION TEST CONFIGURATION

3.1.4.2.2 Measurements of waveform distortion were made at all four sampling rates with CVSD coding technique; the results were identical for log CVSD technique. Testing was performed on a channel which had been modified with the 0.47 microfarad capacitor (see paragraph 2.3) and on an unmodified channel. A square wave signal was used in eachcase as representative of the worst type of slope overload input.

3.1.4.3 Results and Analysis.

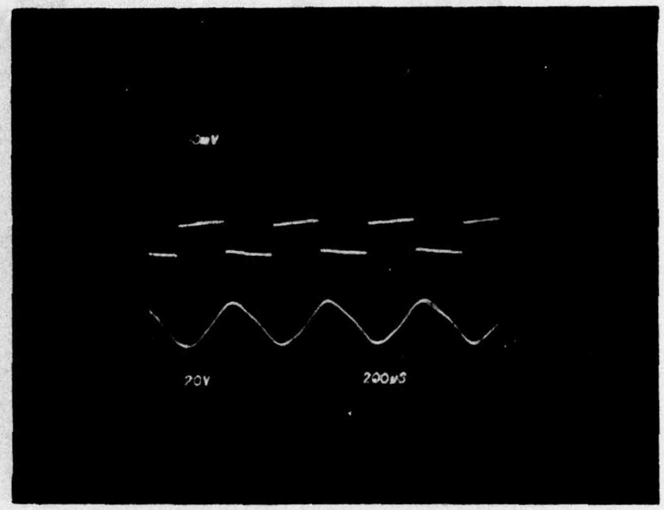
3.1.4.3.1 Figure 13 shows the function generator outputs and ULM-101 outputs for -10 dBm 1800 Hz signal. The upper photograph shows the waveform for a 64 kbps sampling rate; the lower photograph shows the waveform for an 8 kbps sampling rate, with quantizing distortion clearly evident. The waveforms for 16 and 32 kbps were identical to that for 64 kbps. The modified channel was used for these measurements. The waveforms shown are the result of both slope overload and bandwidth effects in the multiplexer channel circuitry.

3.1.4.3.2 Figure 14 shows the function generator outputs and ULM-101 outputs for a 500 Hz square wave at -10 dBm and -20 dBm input levels at the input to the modified channel of the multiplexer. The upper photograph shows the type of waveform obtained for all four sampling rates with a -10 dBm input level. Slope overload and bandwith limiting are still evident, but the reproduction of the input waveform is better than with an 1800 Hz signal. The lower photograph shows the type of waveform obtained for all sampling rates with a -20 dBm input level. The output waveform is degraded, with a very low signal-to-noise ratio.

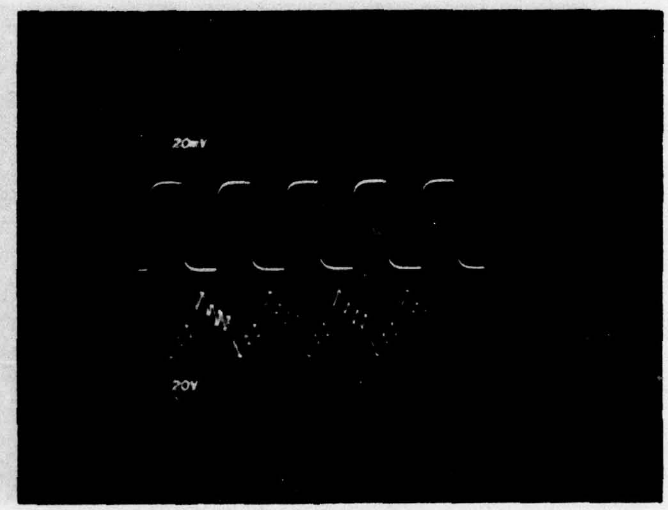
3.1.4.3.3 Figure 15 shows the function generator outputs and ULM-101 outputs for a 1750 Hz square wave at a -10 dBm input level at the unmodified channel of the multiplexer. The upper photograph shows the type of waveform obtained for sampling rates of 32 and 64 kbps; this waveform is virtually identical to that obtained with the modified channel with a -10 dBm, 1800 Hz square wave input. The lower photograph shows the type of waveform obtained for sampling rates of 8 and 16 kbps; the ringing on the waveform obtained for a similar input signal to the modified channel is missing from the waveform.

3.1.4.3.4 Figure 16 shows the function generator outputs and ULM-101 outputs for a 500 Hz square wave at a -10 dBm input level at the unmodified channel of the multiplexer. The upper photograph shows the type of waveform obtained for sampling rates of 16, 32, and 64 kbps. The effects of slope overload are relatively minor, the waveform is reproduced fairly accurately. The lower photograph shows the type of waveform obtained for a sampling rate of 8 kbps. The waveform is recognizable as a square wave, although slope overload effects are still clearly evident.

3.1.4.3.5 Figure 17 shows the function generator outputs and ULM-101 outputs for a 900 Hz square wave at a -20 dBm input level at the unmodified channel of the multiplexer. The upper photograph on the left, representative of sample rates of 16, 32, and 64 kbps, show similar results to those obtained for

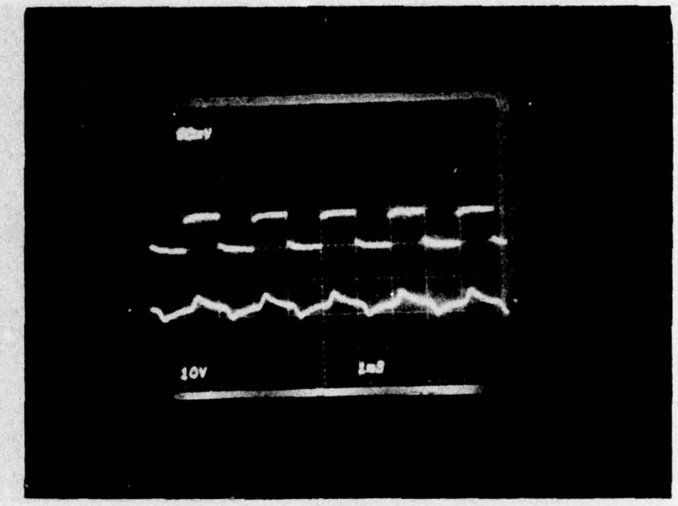


64 KBPS RATE

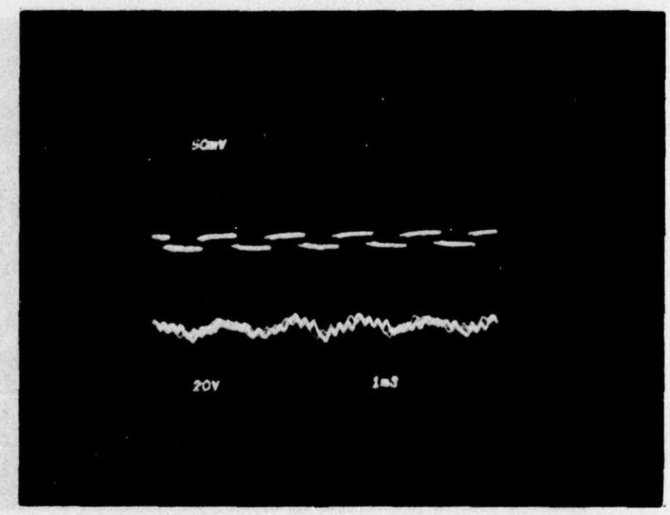


8 KBPS RATE

Figure 13. Waveform Distortion Test, -10 dBm, 1800 Hz Square Wave Input

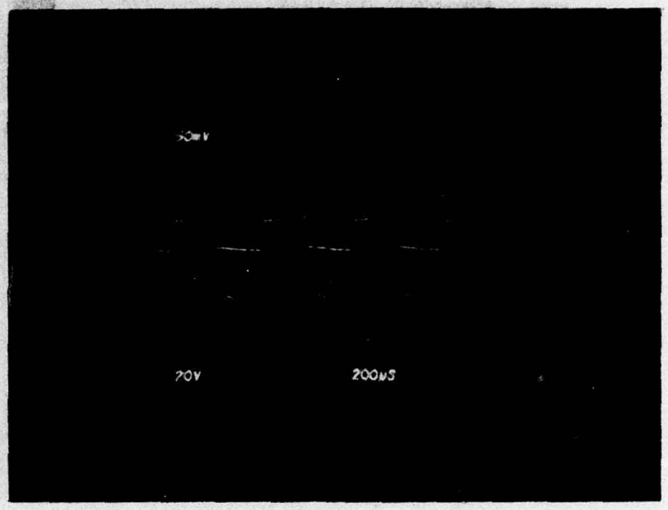


-10 dBm Input

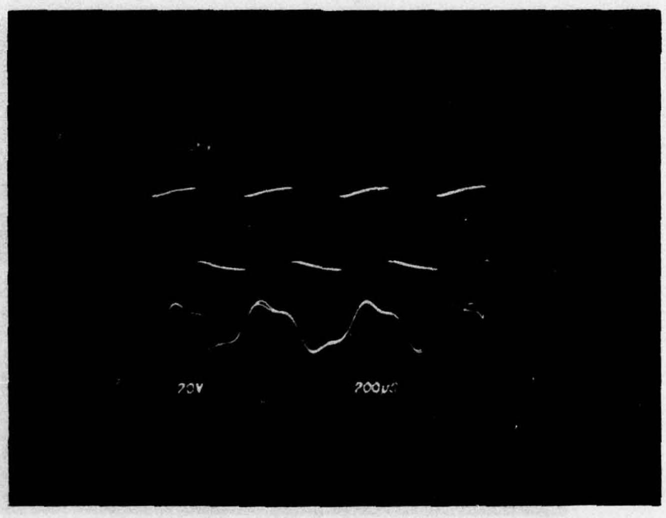


-20 dBm Input

Figure 14. Waveform Distortion Test, 500 Hz
Square Wave Input

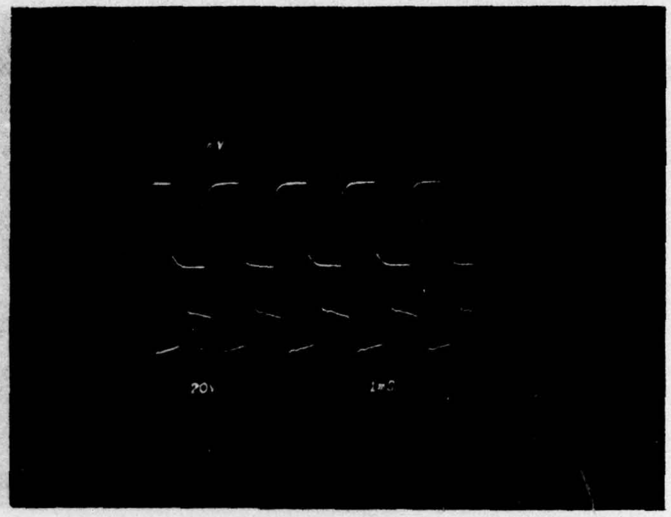


64 KBPS RATE

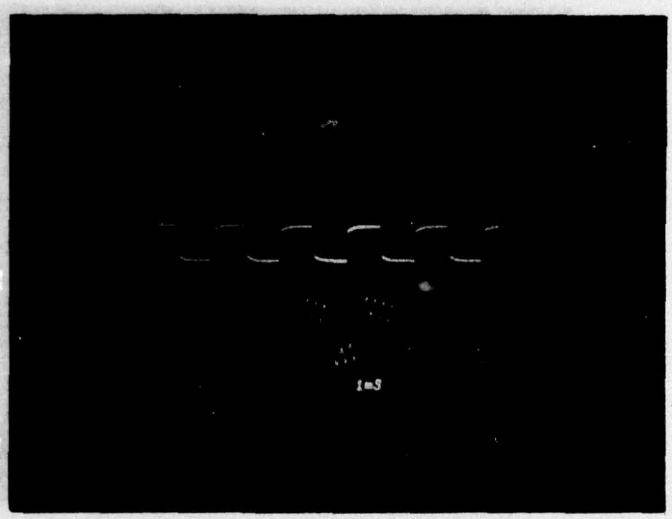


16 KBPS RATE

Figure 15. Waveform Distortion Test, -10 dBm, 1750 Hz Square Wave Input

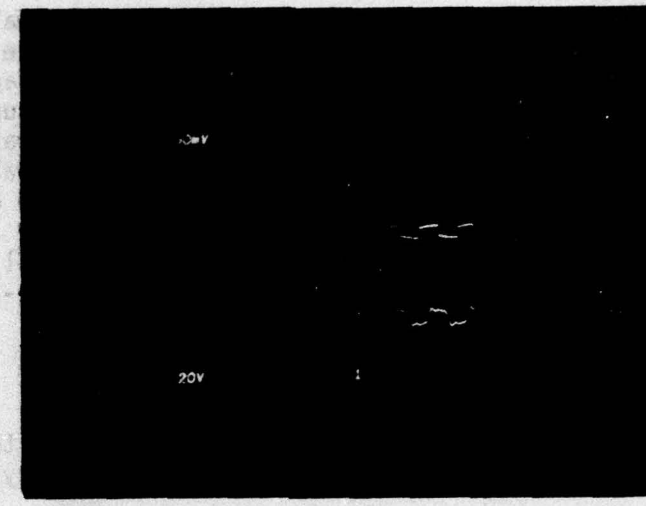


64 KBPS RATE

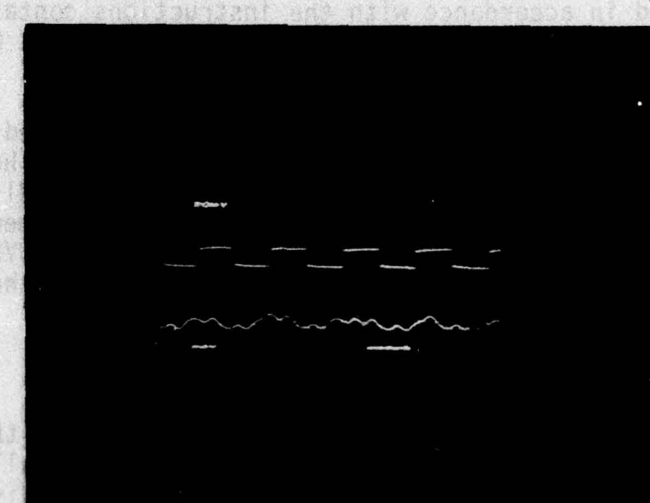


8 KBPS RATE

Figure 16. Waveform Distortion Test, -10 dBm, 500 Hz Square Wave Input



64 KBPS RATE



8 KBPS RATE

Figure 17. Waveform Distortion Test, -20 dBm, 900 Hz Square Wave Input

the -10 dBm, 500 Hz input. The lower photograph, representative of a sampling rate of 8 kbps, shows the signal to be very noisy. The same result was obtained with the modified channel for a similary input signal.

3.1.4.3.6 The results of this test indicate that at a normal operating level of -10 dBm, slope overload effects will result in serious deterioration of any input signal above 500 to 900 Hz with a high rate of change of input amplitude. The ULM-101, as modified for the envelope delay measurement, will not operate without slope overload effect for fast transition waveforms down to the minimum reception level. The unmodified ULM-101 is capable of reproducing a square wave up to 900 Hz at levels between -10 dBm to -20 dBm with some distortion, but with satisfactory accuracy. The difference between the unmodified and modified performance is due to the additional low frequency filtering on the modified channel, which, in effect, double-integrates the output waveform.

3.1.5 Envelope Delay Distortion Test.

3.1.5.1 Objective. The purpose of this test is to define the envelope delay characteristics of the ULM-101 analog input/output circuitry.

3.1.5.2 Procedure.

3.1.5.2.1 Figure 18 depicts the equipment configuration for this test. The test was conducted in accordance with the instructions contained in the manual for the Hewlett-Packard Model 4940A Transmission Impairment Measurement Set (TIMS).

3.1.5.2.2 The Envelope Delay Measurement test was attempted at input levels of 0 dBm and -13 dBm at the analog input to the ULM-101. The TIMS was unable to establish a loop at a 0 dBm input for any ULM-101 channel rate, so no measurements were made. At a -13 dBm input level, measurements were made at multiplexer channel rates of 16, 32, and 64 kbps for both CVSD and log CVSD coding techniques. At 8 kbps with both coding techniques the TIMS was unable to establish a loop condition.

3.1.5.3 Results and Analysis.

3.1.5.3.1 The loss of loop by the TIMS test set indicates that the 83 1/3 Hz modulation frequency is lost. At a 0 dBm input level for all sampling rates and an 8 kbps sampling rate at a -13 dBm input level, the distortion of the signal is great enough for the TIMS to interpret the carrier as lacking the required modulation frequency and the set either fails to achieve phase lock or breaks the loop.

3.1.5.3.2 Figures 19 through 21 show the curves of envelope delay as a function of frequency for CVSD coding technique and channel sampling rates of 16, 32, and 64 kbps. Virtually identical results were obtained for log CVSD coding techniques. The test set lost loop at 2400 Hz for a 16 kbps sampling rate, 3200 Hz for a 32 kbps sampling and was still in loop at 3900 Hz for a 64 kbps sampling rate where the test was terminated.

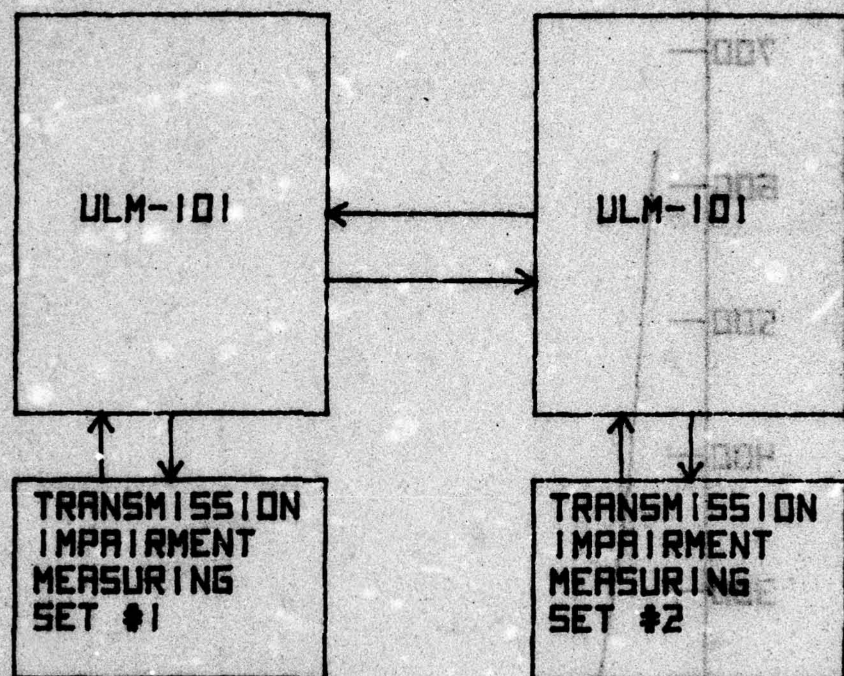


FIGURE 18. ENVELOPE DELAY TEST CONFIGURATION

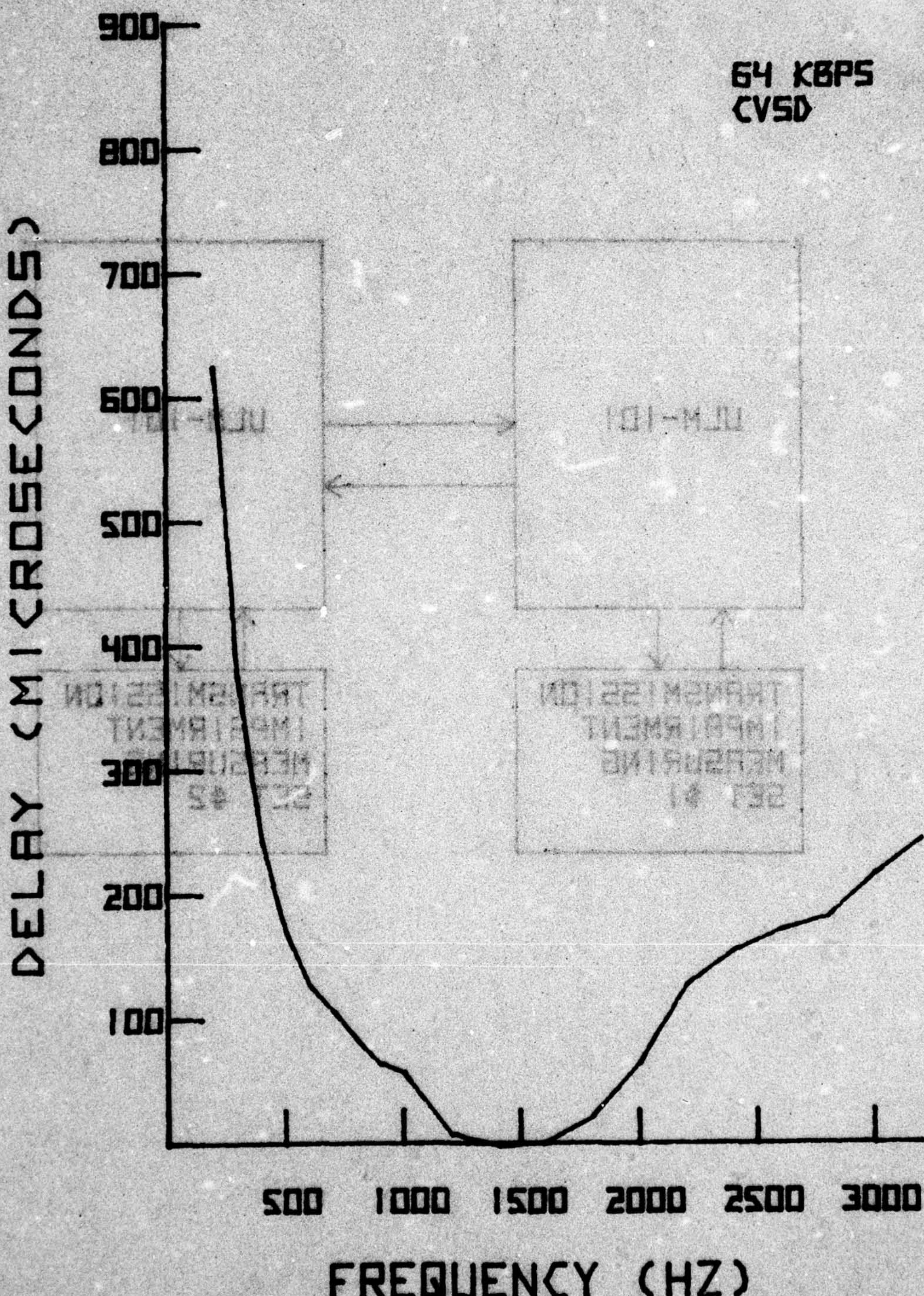


FIGURE 19. ENVELOPE DELAY VS FREQUENCY

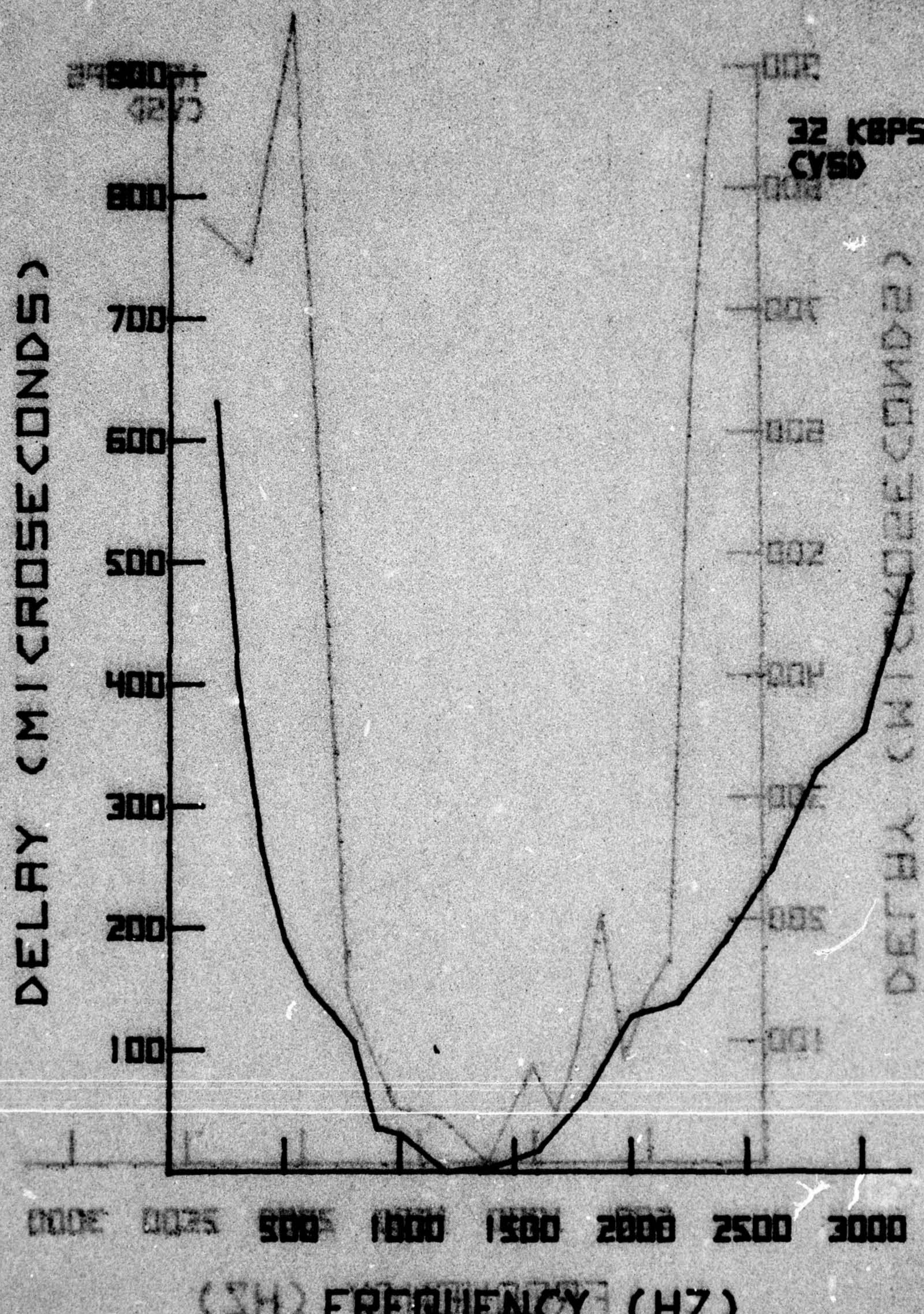


FIGURE 20. ENVELOPE DELAY VS FREQUENCY

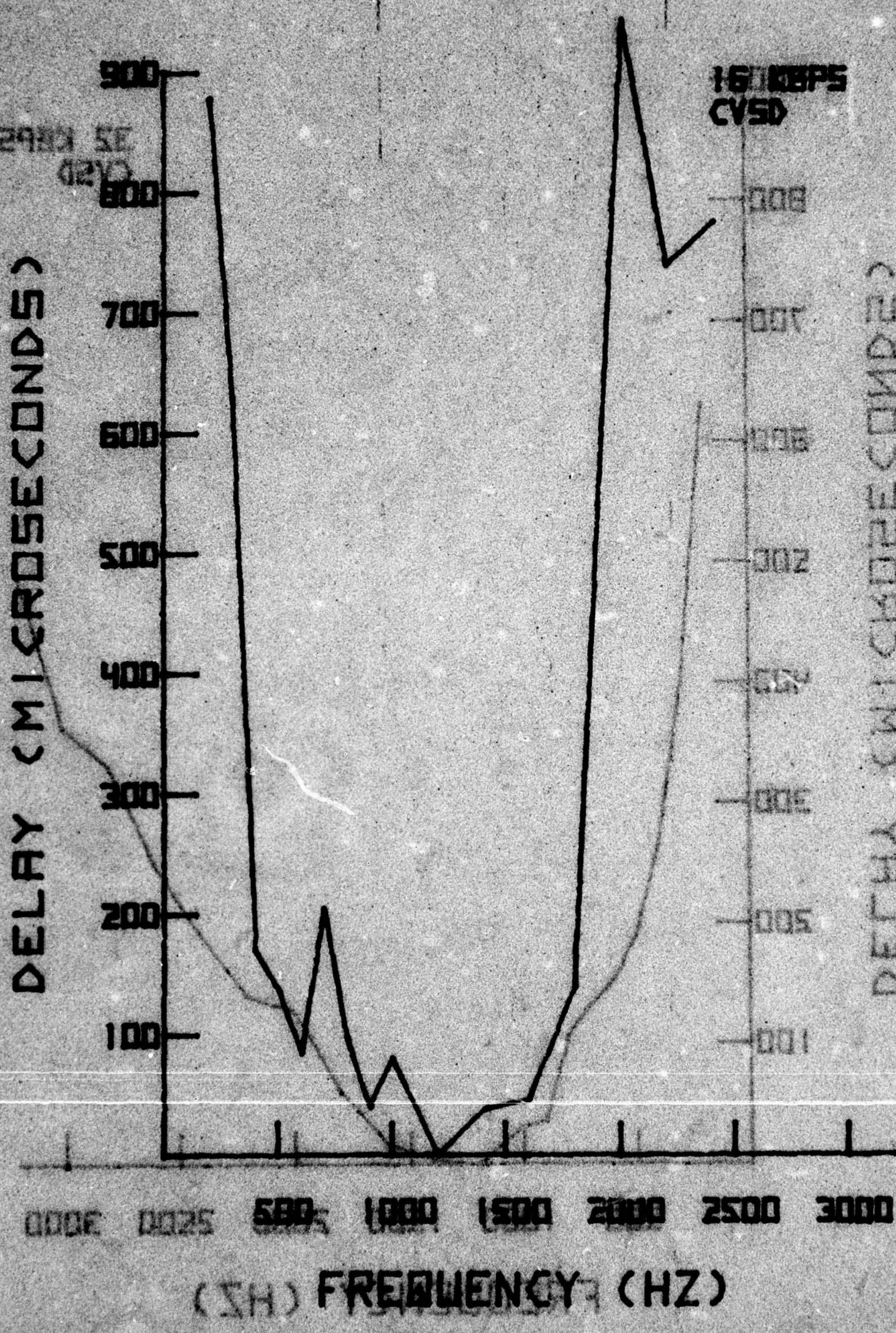


FIGURE 21. ENVELOPE DELAY VS FREQUENCY

3.1.5.3.3 A comparison of the results shown in figures 19-21 with the requirements of DCA Circular 300-175-9, Table II, indicates that the ULM-101 meets the requirements for the circuit parameters for envelope delay as follows. At a 16 kbps channel sampling rate, none of the parameter requirements are met due to the limited bandwidth in which the envelope delay is capable of being measured. At a 32 kbps channel rate, the ULM-101 meets the criteria for circuit parameters S2, D1 and D2. At a 64 kbps channel sampling rate, the ULM-101 meets the criteria for circuit parameters S2, D1 and D2 and is close to meeting the requirements for S3.

3.1.6 <u>Phase Jitter Test</u>.

3.1.6.1 Objective. The purpose of this test is to define the phase jitter characteristics of the ULM-101 analog input/output circuitry.

3.1.6.2 Procedure.

3.1.6.2.1 Figure 22 depicts the equipment configuration for this test. The test was conducted in accordance with the instructions contained in the manual for the Hewlett-Packard Model 4940A Transmission Impairment Measuring Set (TIMS).

3.1.6.2.2 The phase jitter measurement was performed at all four channel rates and both coding techniques for all four active channels of the ULM-101. The test was performed at input signal levels of 0 dBm and -13 dBm.

3.1.6.3 Results and Analysis.

3.1.6.3.1 Table IV contains a summary of the phase jitter measurements performed on the ULM-101. At an input level of 0 dBm, the phase jitter is greater than 25 degrees for channel sampling rates of 8 and 16 kbps for all four channels and for both CVSD and log CVSD coding techniques. At an input level of -13 dBm intermodulation distortion effects are reduced to the point where readings of less than 25 degrees can be obtained for the 16 kbps channel sampling rate; although 8 kbps sampling rate still yields phase jitter results in excess of 25 degrees.

3.1.6.3.2 The data in Table IV reveals very similar results for all four ULM-101 channels irrespective of coding technique, channel sampling rate, or input level. The phase jitter with a -13 dBm input is consistenly lower than that observed for a 0 dBm input. The phase jitter is lower as the sampling rate increases as would be expected. There are no significant differences between the two coding techniques shown in the phase jitter results.

3.1.6.3.3 Table II of DCA Circular 300-175-9 states a peak jitter of 15 degrees as being a requirement for circuit parameters S1 through S3 and D1 and D2. The ULM-101 meets this criteria at sampling rates of 32 and 64 kbps for input levels of 0 dBm and -13 dBm and at a sampling rate of 16 kbps for an input level of -13 dBm.

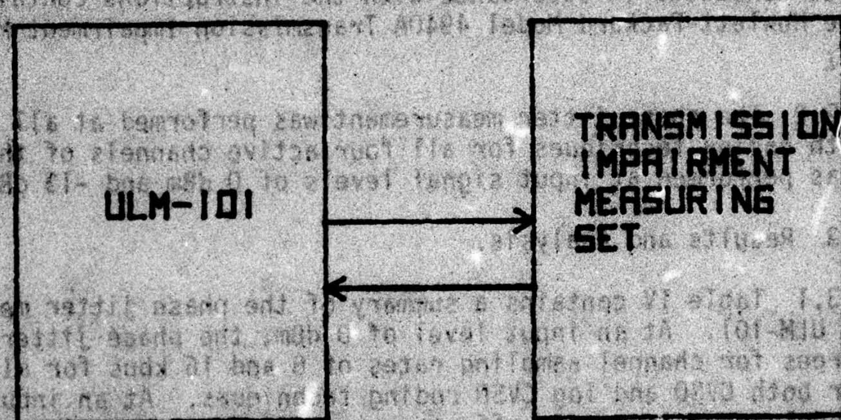


FIGURE 22. PHASE JITTER TEST CONFIGURATION

TABLE IV. PHASE JITTER MEASUREMENT SUMMARY

Channel Number	0 dBm Input								-13 dBm Input							
	CVSD Chan Rate				LOG CVSD Chan Rate				CVSD Chan Rate				LOG CVSD Chan Rate			
	8	16	32	64	8	16	32	64	8	16	32	64	8	16	32	64
1	+	+	11.4	9.6	+	+	11.8	9.4	+	11.4	4.3	3.1	+	11	4.8	3.0
2	+	+	12.1	9.5	+	+	12	9.4	+	11.7	5.7	2.8	+	11.9	5.5	2.8
3	+	+	12.4	11.4	+	+	12.3	11.1	+	13.4	5.7	3.9	+	13.2	5.1	3.1
4	+	+	12.2	12	+	+	12.3	9.5	+	13.1	5.2	3.0	+	12.6	5.4	2.9

+ = Phase Jitter greater than 25^{o}.

3.1.7 Idle Channel Noise Test.

3.1.7.1 Objective. The purpose of this test is to define the idle channel noise level of the ULM-101.

3.1.7.2 Procedure.

3.1.7.2.1 The equipment procedure for this test is identical to that shown in figure 22. The test was conducted in accordance with the instructions contained in the manual for the Hewlett-Packard Model 4940A Transmission Impairment Measuring Set (TIMS).

3.1.7.2.2 An idel channel noise measurement was performed at all four channel sampling rates and both coding techniques for all four active channels of the ULM-101. The test was conducted using both C-Message and 3 KHz flat filters in the TIMS.

3.1.7.3 Results and Analysis.

3.1.7.3.1 Table V contains a summary of the idle channel noise measurements performed on the ULM-101. The measurements are in terms of noise power, DBRNC for C-Message filtering of the input and DBRN for a 3 KHz flat filter. The conversion factor for translating the units into signal power units is dBm = DBRN-90. The wider bandwidth of the 3 KHz filter intercepts more of the noise resulting in a 2 dB higher noise power reading.

3.1.7.3.2 A review of Table V shows that channel 1 of the ULM-101 has the best noise performance, approximately 3 dB better than the worst channel, channel 4. Table V shows that the noise level is identical for channel sampling rates of 8 and 16 kbps and again for sampling rates of 32 and 64 kbps. The noise level is 2-5 dB lower at 32 and 64 kbps sampling rates than at 8 and 16 kbps sampling rates. The noise level with CVSD coding is 2-4 dB higher than with the log CVSD coding technique.

3.1.7.3.3 The noise level of a digital multiplexer is essentially determined by the granularity of the quantizing process, since the noise level of the analog circuitry is usually insignificant with respect to the smallest quantization level of the analog-to-digital converter.

3.1.7.3.4 Due to the fact that an analog-to-digital system has a noise floor which is dependent on the quantization, the circuit performance parameters of DCA Circular 300-175-9, Table II cannot be used for comparison. For example, the ULM-101 fails to meet the channel noise requirements for links up to 644 kilometers long, but meets the criteria for links between 644 and 2574 kilometers long.

3.1.8 Loop Test.

3.1.8.1 Objective. The purpose of this test is to determine the number of times the ULM-101 can be looped at channel level without creating an unuseable link.

TABLE V. IDLE CHANNEL NOISE MEASUREMENT SUMMARY

Channel Number	CVSD CODING								LOG CVSD CODING							
	C-MSG Noise Power (DBRNC)				3kHz Noise Power (DBRN)				C-MSG Noise Power (DBRNC)				3kHz Noise Power (DBRN)			
	8	16	32	64	8	16	32	64	8	16	32	64	8	16	32	64
1	43	43	39	39	44	44	41	41	39+	39+	38	38	41	41	39	39
2	42	42	36	36	44	43	38	38	37+	37+	33	33	39	39	35	35
3	40	40	35	35	42	42	36	37	33	33	31	31	34+	34+	33+	33+
4	39+	39+	34	34	41	41	37	37	37	37	32	32	39	39	36	36

3.1.8.2 Procedure.

3.1.8.2.1 The equipment interconnections for this test are shown in figure 23 for two loops at channel level. The transmit connection from the TIMS provides a quiet 600 ohm termination for the CVSD #1 channel input. The receive input to the TIMS is connected to the output of the last channel in the loop. An idle channel noise measurement is performed in this configuration. The idle channel noise measurement was chosen as the best indication of loop performance, the point where the system is noise limited.

3.1.8.2.2 The loop test was performed at all four sampling rates and both coding techniques for successive number of channel loopbacks of the ULM-101 up to the maximum number of six. The test was conducted using C-Message weighting in the TIMS.

3.1.8.3 Results and Analysis.

3.1.8.3.1 Figures 24 and 25 show the increase in idle channel noise with successive loopbacks for both CVSD and log CVSD coding techniques with C-Message weighting.

3.1.8.3.2 Figure 24 shows that for CVSD coding the noise increases as the number of loopbacks increases with the exception of the 8 kbps sampling rate at five loopbacks. The behavior at 8 kbps is presently unexplained. Figure 25 reveals somewhat different behavior with log CVSD coding. The noise level is approximately constant up to four or five for 32 and 64 kbps sampling rates, at which point the noise level increases with each increasing number of loopbacks. The behavior at 16 kbps is similar to that with CVSD coding; the behavior at an 8 kbps sampling rate is somewhat anomolous.

3.1.9 <u>Signal-to-Quantizing Noise Ration (S/Nq) Test</u>.

3.1.9.1 Objective. The purpose of this test is to determine the S/Nq of the ULM-101 as a function of input level.

3.1.9.2 Procedure.

3.1.9.2.1 The equipment configuration for this test is shown on figure 26. The audio oscillator output level was adjusted to provide a 0 dBm level at the input to the ULM-101 with the attenuation to 0 dBm. Then the attenuator was used to vary the input level to the multiplexer between the measurement limits of 0 dBm and -40 dBm. The audio oscillator was tuned to a frequency of 1010 Hz. The frequency selective voltmeter was tuned to the maximum of the output signal from the ULM-101 and a measurement of the level of this signal was made with the voltmeter set to a 10 Hz measurement bandwidth. The transformer was used as a balanced to unbalanced matching device. The noise measuring set used was a Northeast Electronics Model TTS-37BAQCN which contains

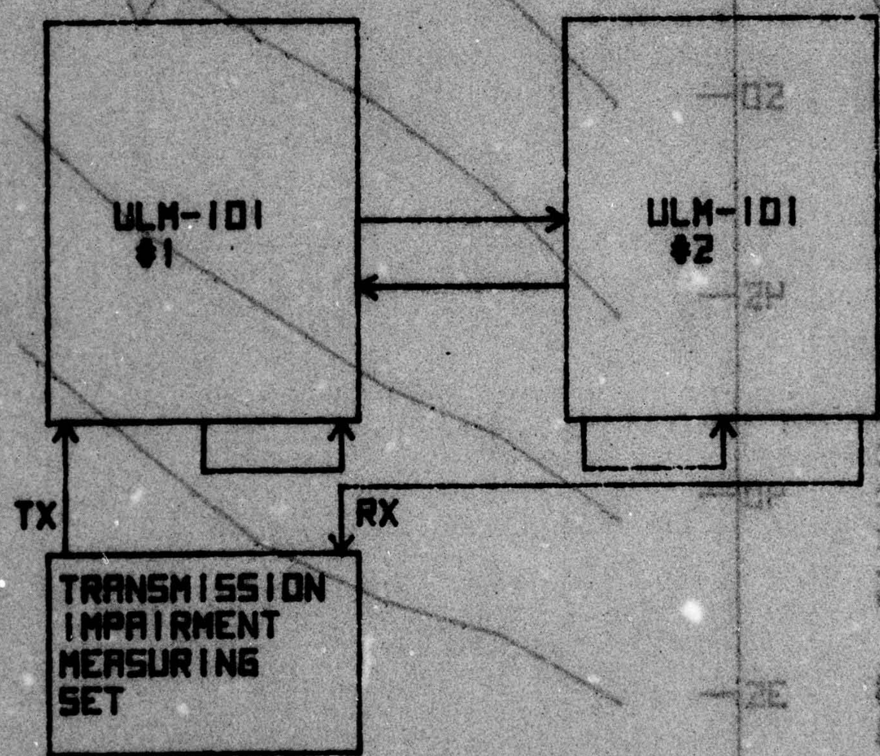


FIGURE 23. LOOPBACK TEST CONFIGURATION

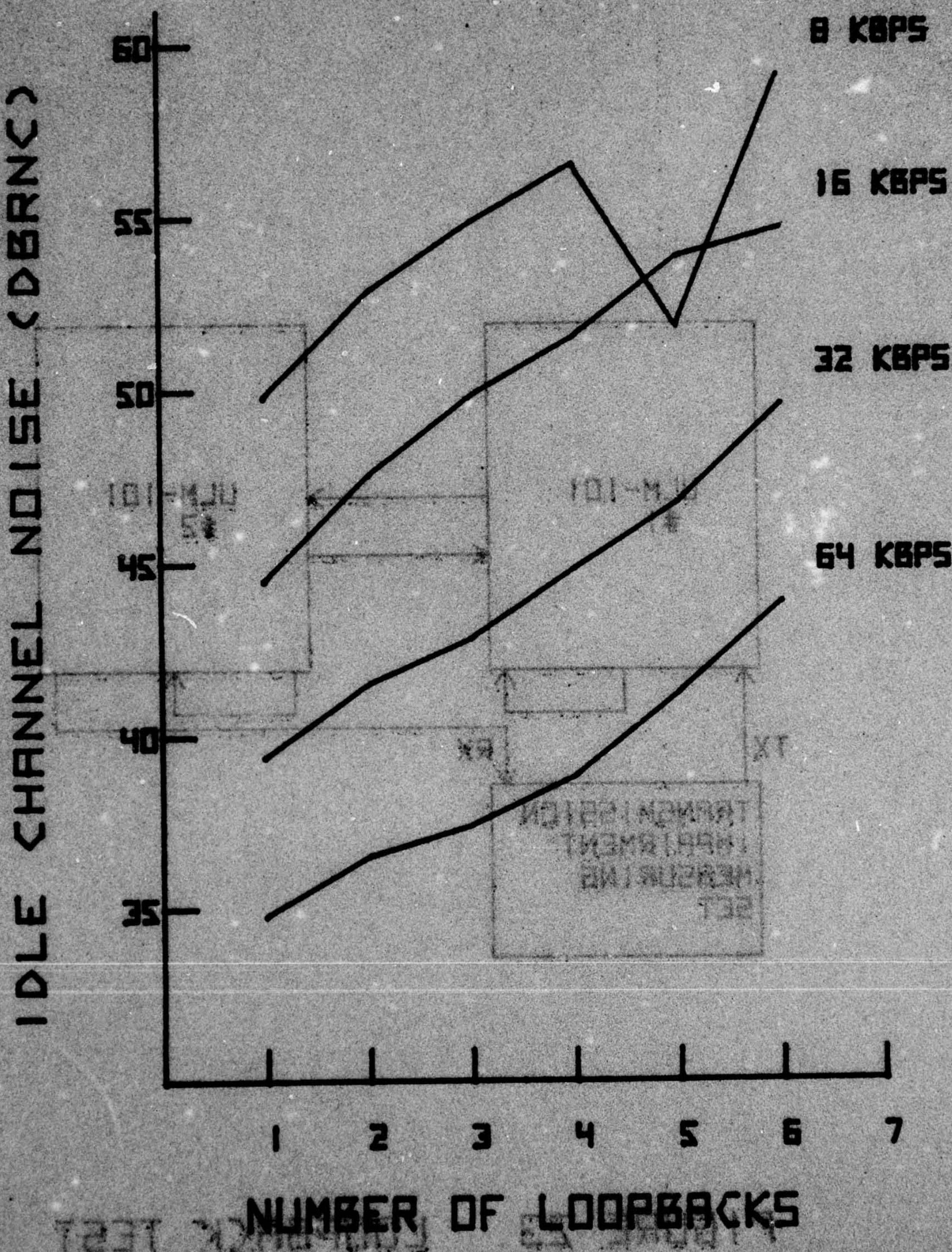


FIGURE 24. LOOP TEST RESULTS, (CVSD)

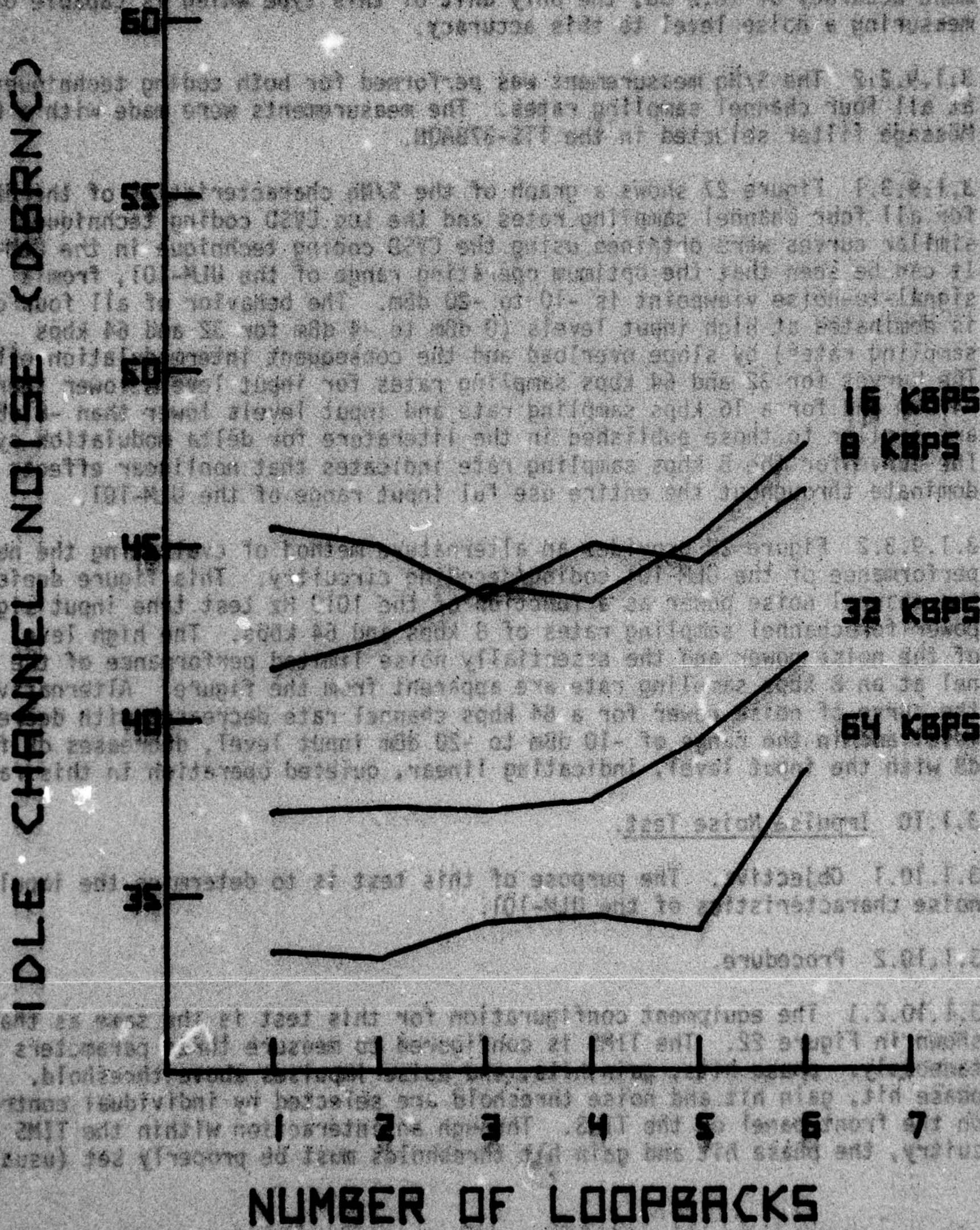


FIGURE 25. LOOP TEST RESULTS, LOG(VSD)

a 1010 Hz notch filter to allow a measurement of noise power to be performed with the 1010 Hz input signal notched out. The TTS-37 BAQN also has a measurement accuracy of +0.2 dB, the only unit of this type which is capable of measuring a noise level to this accuracy.

3.1.9.2.2 The S/Nq measurement was performed for both coding techniques and at all four channel sampling rates. The measurements were made with a C-Message filter selected in the TTS-37BAQN.

3.1.9.3.1 Figure 27 shows a graph of the S/Nq characteristics of the ULM-101 for all four channel sampling rates and the Log CVSD coding technique. Very similar curves were obtained using the CVSD coding technique in the ULM-101. It can be seen that the optimum operating range of the ULM-101, from a signal-to-noise viewpoint is -10 to -20 dBm. The behavior of all four curves is dominated at high input levels (0 dBm to -4 dBm for 32 and 64 kbps sampling rates) by slope overload and the consequent intermodulation effects. The curves for 32 and 64 kbps sampling rates for input levels lower than -4 dBm and for a 16 kbps sampling rate and input levels lower than -8 dBm are similar to those published in the literature for delta modulation systems.[2] The curve for the 8 kbps sampling rate indicates that nonlinear effects predominate throughout the entire use ful input range of the ULM-101.

3.1.9.3.2 Figure 28 provides an alternatuve method of evaluating the noise performance of the ULM-101 coding/decoding circuitry. This figure depicts the channel noise power as a function of the 1010 Hz test tone input signal power for channel sampling rates of 8 kbps and 64 kbps. The high level of the noise power and the essentially noise limited performance of the channel at an 8 kbps sampling rate are apparent from the figure. Alternatively, the curve of noise power for a 64 kbps channel rate decreases with decreasing level and in the range of -10 dBm to -20 dBm input level, decreases dB for dB with the input level, indicating linear, quieted operation in this range.

3.1.10 Impulse Noise Test.

3.1.10.1 Objective. The purpose of this test is to determine the impulse noise characteristics of the ULM-101.

3.1.10.2 Procedure.

3.1.10.2.1 The equipment configuration for this test is the same as that shown in Figure 22. The TIMS is configured to measure three parameters simultaneously: phase hits, gain hits, and noise impulses above threshold. The phase hit, gain hit and noise threshold are selected by individual controls on the front panel of the TIMS. Through an interaction within the TIMS circuitry, the phase hit and gain hit thresholds must be properly set (usually

[2] Steele, "Delta Modulation Systems," John Wiley and Sons, New York (1975)

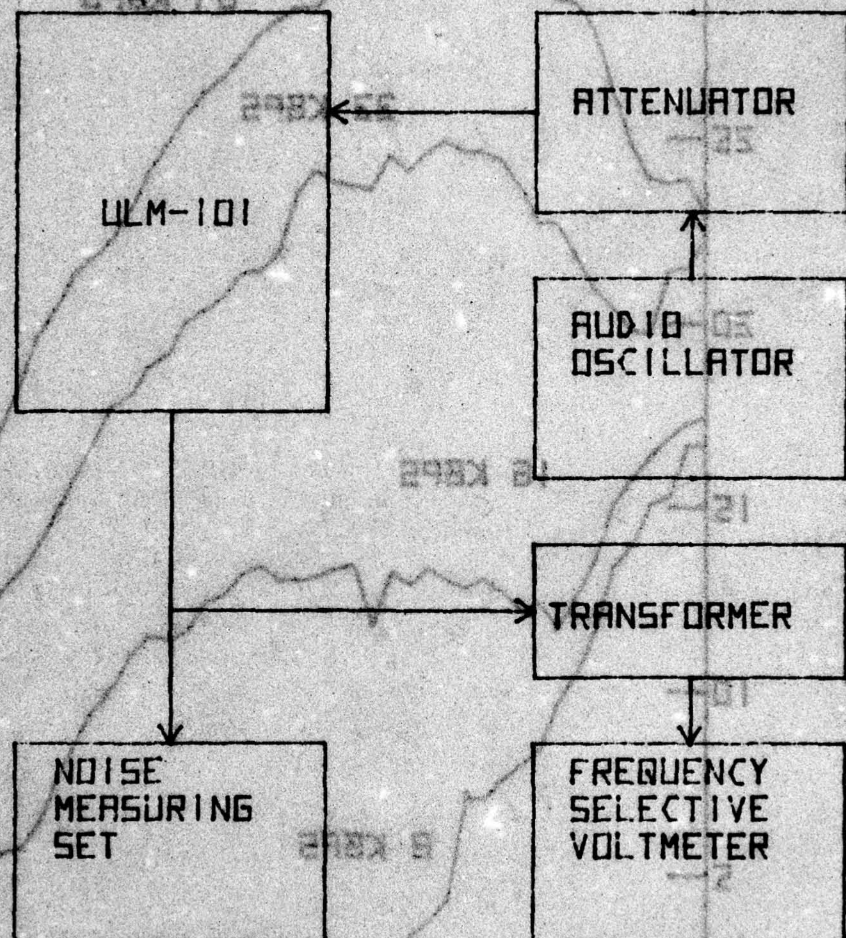


FIGURE 26. QUANTIZING NOISE CONFIGURATION

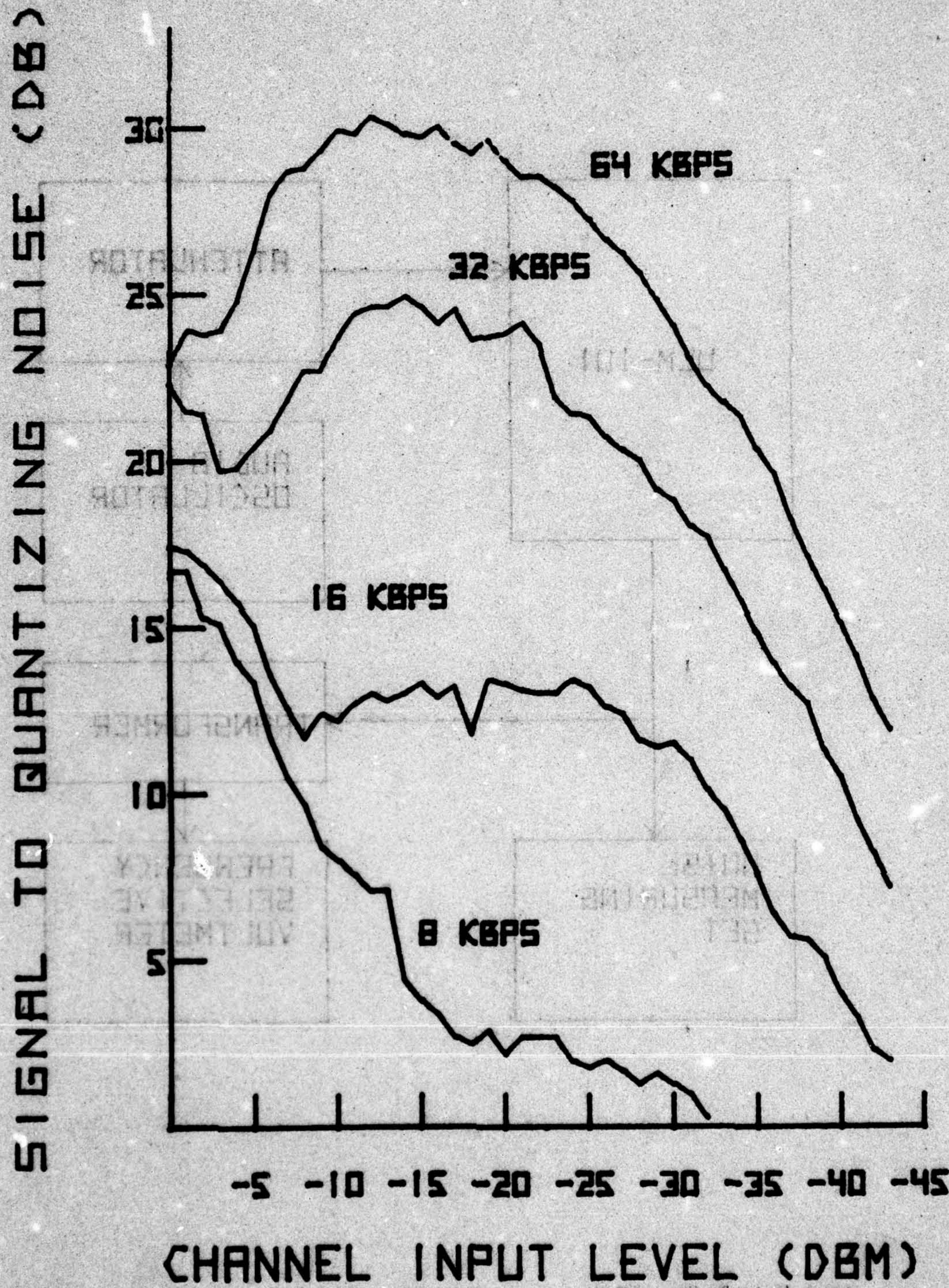


FIGURE 27. SIGNAL TO QUANTIZING NOISE CHARACTERISTICS

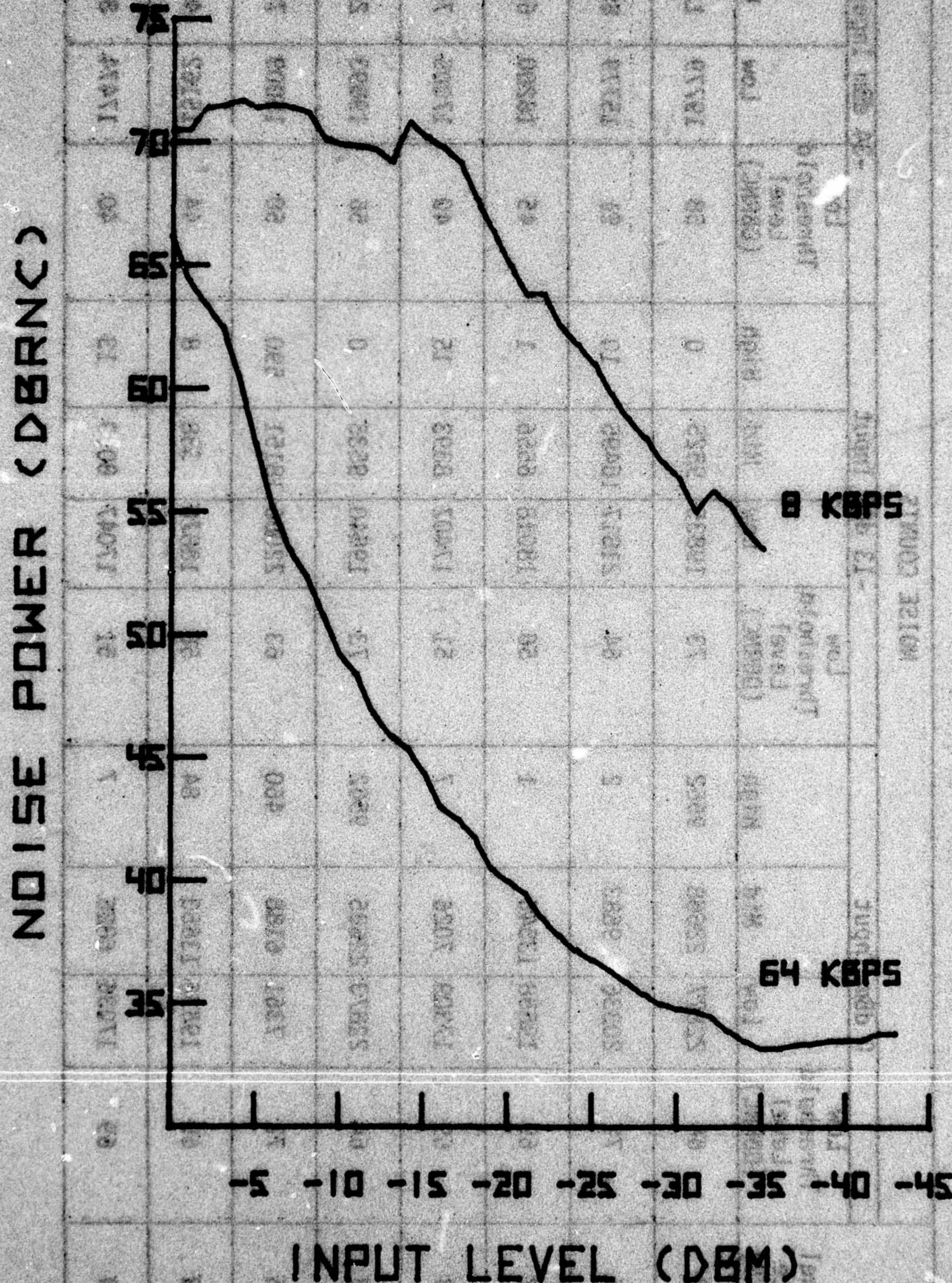


FIGURE 28. NOISE POWER VS INPUT LEVEL

TABLE VI. IMPULSE NOISE SUMMARY

Coding Technique	Channel Rate (KBPS)	NOISE COUNTS: 0 dBm Input: Low Threshold Level (DBRNC)	0 dBm Input: Low	0 dBm Input: Mid	0 dBm Input: High	-13 dBm Input: Low Threshold Level (DBRNC)	-13 dBm Input: Low	-13 dBm Input: Mid	-13 dBm Input: High	-34 dBm Input: Low Threshold Level (DBRNC)	-34 dBm Input: Low	-34 dBm Input: Mid	-34 dBm Input: High
CVSD	8	64	22877	22668	9562	73	19835	9525	0	58	19779	12511	7
	16	72	20336	9683	2	64	21817	16495	10	51	15779	8908	30
	32	69	19558	13545	1	56	18018	6556	1	45	16200	6502	5
	64	69	17309	7026	7	51	17407	8893	15	40	17005	7539	6
LOG CVSD	8	64	22873	22695	9562	73	19840	9535	0	56	19893	2657	17
	16	72	7361	6188	460	63	22086	18151	590	50	15009	7046	3
	32	69	19536	13653	84	56	18876	388	8	44	15162	4482	4
	64	69	17036	6826	7	51	17047	8039	13	40	17474	8776	20

at high values) to obtain the proper reading of impulse noise hits above threshold. The low threshold for noise impulses was set, as much as possible, to a level which would give 5 to 15 counts in a 5 minute period. With the TIMS test set, the mid-threshold is then 4 dB higher than the low threshold and the high threshold is 8 dB higher than the low threshold. The C-message noise filter on the TIMS was used for this test.

3.1.10.2.2 The TIMS has switch selection of two different count rates -Bell Standard (limited to 7 counts per second) and Channel Limited (limited by noise bandwidth to 75 counts per second). The test was conducted using the channel limited setting as this provides data more consistent with digital performance.

3.1.10.2.3 The impulse noise test was conducted for all four channel sampling rates, both coding techniques and signal input levels of 0 dBm, -13 dBm, and -34 dBm. The TIMS uses a 1004 Hz signal as the test tone to perform this measurement.

3.1.10.3 <u>Results and Analysis</u>.

3.1.10.3.1 Table VI summarizes the results of this test. It can be seen that roughly equivalent results were obtained for both coding techniques with perhaps slightly more sensitivity to impulse noise bwing shown with Log CVSD coding technique. The results of Table VI show a decrease in the level of the low threshold noise power with a decrease in the input signal power as well as a decrease in the low threshold level with an increase in sampling rate. The 32 and 64 kbps sampling rates also show the effects of the slope overload (overload noise products predominent) at a 0 dBm input level.

3.1.10.3.2 Testing with the ULM-101 showed that a definite noise floor exists for the impulse noise counts. For example, a 72 dBrnc low threshold level at 8 kbps sampling rate and -13 dBm input level resulted in continuous counts in all three categories. A one dB increase in the level for the three counters resulted in zero counts in a five minute period in the HI counter.

3.1.10.3.3 The predominant factor in these impulse noise measurements is quantization noise. The low threshold level in each case is 4-8 dB below the level of quantization noise in the presence of a signal so the low and mid range counters are counting this noise. Once past the level of quantization noise the ULM-101 channel input circuitry is essentially quiet. The performance of the ULM-101 in a central office with normal "clicks", "pops", and "hisses" typical in those types of circuits would depend on the spectral distribution of the interference.

3.1.11 <u>Nonlinear Distortion Test</u>.

3.1.11.1 Objective. The purpose of these tests is to determine the level of nonlinear distortion present in the analog output of the ULM-101.

3.1.11.2 Procedure.

3.1.11.2.1 Two different equipment configurations were used for this test. The first configuration, which employs the HP 4940 TIMS, is identical to that shown on figure 22. In the nonlinear distortion test utilizing this configuration, two tones, at 860 Hz and 1380 Hz, are simultaneously introduced into the ULM-101 channel input and the second and third order distortion products are measured. Second order distortion is represented by the power sum of $f_1 + f_2$ and f_2 and f_1 distortion products. Third order distortion is represented by the $2f_2 - f_1$ distortion product.

3.1.11.3.2 The second configuration used for this test is shown on figure 29. For this test, the audio oscillator was set to 1000 Hz and the frequency selective voltmeter was used to measure the signal present at 1000, 2000, 3000, 4000, and 5000 Hz. The measurement was made with the frequency selective voltmeter in the 10 Hz bandwidth position.

3.1.11.3.3 The two types of measurements of nonlinear distortion were performed for both coding techniques and at all four channel sampling rates of the ULM-101. Input levels of 0, -10, -13, and -16 dBm were used for the test.

3.1.11.3 Results and Analysis.

3.1.11.3.1 Table VII shows the results of the nonlinear distortion measurements made with the TIMS. It can be seen that there is no significant difference between the results obtained with CVSD coding and those obtained using log CVSD coding. At input levels of -10, -13, and -16 dBm for channel sampling rates of 8, 16, and 32 kbps, the level of the second order and third order products are approximately the same. With a sampling rate of 64 kbps at these input levels, the third order products are significantly lower than the second order products. At an input level of 0 dBm, the third order products are significantly higher than the second order products, and also higher than the third order products at lower input levels, again a result of slope overload effects.

3.1.11.3.2 Table VIII presents the results of the harmonic distortion measurements made with the frequency selective voltmeter. The measurement accuracy at low power levels is only ±10 dB due to oscillations of the signal. With this consideration, there is no significant difference between the results with the two coding techniques at the lower input levels; the levels of all the harmonics for a particular channel sampling rate are approximately the same. The results for a 0 dBm input show the strong third harmonic at an 8 kbps sampling rate noted in the nonlinear distortion test. It will be noted that the level of the harmonics for the 8 kbps sampling rate remains reasonably constant as the input level decreases while the level of the harmonics for the other sampling rates decreases in level with input level down to -13 dBm and then remain relatively constant.

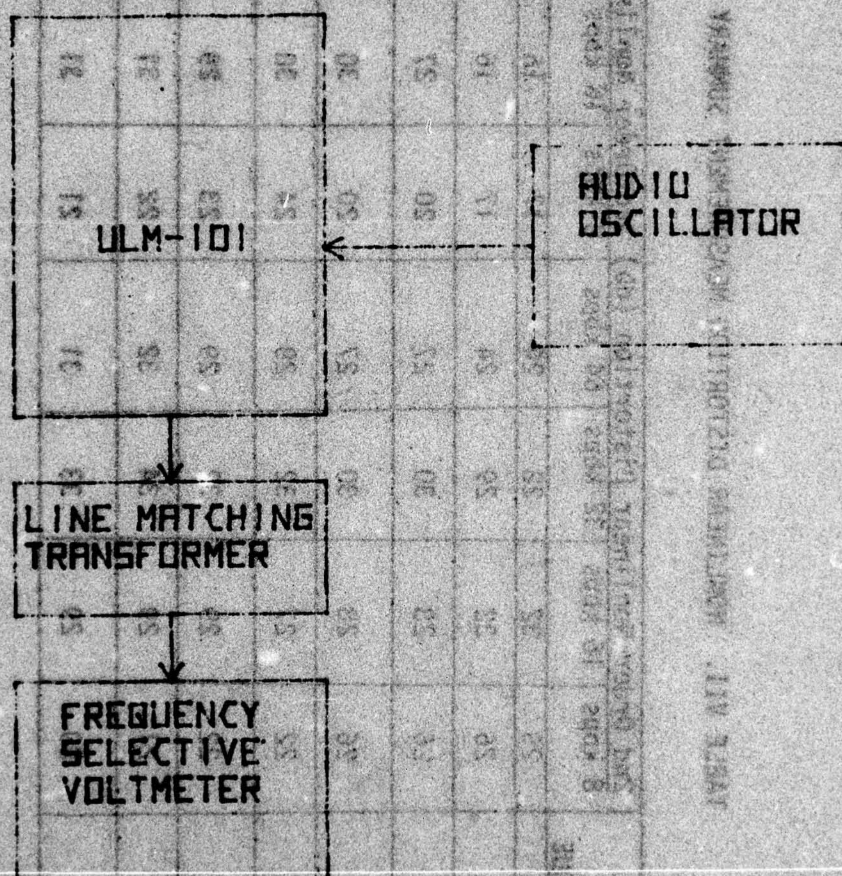


FIGURE 29. HARMONIC DISTORTION TEST CONFIGURATION

TABLE VII. NONLINEAR DISTORTION MEASUREMENT SUMMARY

INPUT LEVEL (dBm)	CHANNEL CODE TECHNIQUE	2nd Order Nonlinear Distortion (db)				3rd Order Nonlinear Distortion (db)			
		8 kbps	16 kbps	32 kbps	64 kbps	8 kbps	16 kbps	32 kbps	64 kbps
0	CVSD	25	32	28	24	17	16	17	18
	LOG CVSD	26	32	29	24	17	16	18	18
-10	CVSD	26	28	30	27	20	27	31	35
	LOG CVSD	26	28	30	27	20	30	30	34
-13	CVSD	22	27	32	29	24	30	36	43
	LOG CVSD	22	29	32	29	23	29	32	41
-16	CVSD	21	29	34	32	22	31	36	46
	LOG CVSD	20	29	33	31	21	31	36	44

TABLE VIII. HARMONIC DISTORTION MEASUREMENT SUMMARY

Input Level (dBm)	Channel Code Technique	Channel Rate (kbps)	Harmonic Level (dBm) 1000 Hz (FUND)	2000 Hz	3000 Hz	4000 Hz	5000 Hz
0	CVSD	8	-3.7	-50	-23	-57	-35
		16	-2.6	-25	-29	-26	-43
		32	-2.8	-33	-29	-38	-35
		64	-2.5	-31	-37	-48	-43
	LOG CVSD	8	-3.8	-50	-22	-57	-44
		16	-2.8	-25	-29	-26	-53
		32	-3.0	-34	-29	-44	-58
		64	-2.8	-31	-38	-50	-65
-10	CVSD	8	-12.7	-21.8	-32	-27	-43
		16	-12.5	-28.5	-40	-30	-47
		32	-12.4	-49	-44	-50	-52
		64	-12.2	-47	-51	-59	-70
	LOG CVSD	8	-13.2	-23	-31	-27	-44
		16	-13.2	-33	-48	-48	-53
		32	-12.8	-50	-40	-54	-56
		64	-12.7	-47	-52	-57	-66
-13	CVSD	8	-12.7	-22	-31	-27	-43
		16	-15.5	-54	-45	-45	-42
		32	-15.4	-50	-48	-51	-45
		64	-15.2	-57	-55	-65	-60
	LOG CVSD	8	-13.5	-23	-32	-27	-45
		16	-16	-51	-48	-29	-45
		32	-16	-48	-51	-58	-56
		64	-15.8	-51	-46	-64	-65
-16	CVSD	8	-17.5	-27	-31	-36	-34
		16	-18.5	-50.1	-51	-55	-60
		32	-18.4	-54	-48	-50	-60
		64	-18	-56	-58	-63	-60
	LOG CVSD	8	-19	-28	-31	-33	-42
		16	-19	-38	-50	-48	-40
		32	-19	-55	-51	-54	-52
		64	-18.8	-55	-56	-65	-60

3.1.12 Three Frequency Intermodulation Distortion.

3.1.12.1 Objective. The purpose of this test is to determine the level of intermodulation products present in a channel output of the ULM-101 with a channel input consisting of three equal level tones.

3.1.12.2 Procedure.

3.1.12.2.1 The equipment configuration for this test is shown on figure 30. Three audio oscillators, tuned to frequencies of 860 Hz, 1380 Hz, and 1900 Hz, respectively, were resistively matched to provide a composite 600 ohm input to the ULM-101. The output levels of the three oscillators were equal and were adjusted to provide a total input signal power at the level desired. The test was conducted with composite signal power of 0 dBm and -13 dBm. The frequency selective voltmeter was used to measure the signal power at each of the second and third intermodulation distortion product frequencies.

3.1.12.2.2 The test was performed for both coding techniques and for all four sampling rates of the ULM-101. The results were recorded on oscilloscope photographs and X-Y plots as well as readings being taken by the frequency selective voltmeter.

3.1.12.3 Results and Analysis.

3.1.12.3.1 There are 21 frequencies in the passband of the ULM-101 where second and third order intermodulation products can appear. The energy of these products is scattered throughout the passband and no one product is significantly higher than the composite noise level. As a result the effort to measure the level of individual products, even with a 10 Hz bandwidth on the frequency selective voltmeter, was largely unsuccessful.

3.1.12.3.2 The X-Y plot of the ULM-101 channel output resulting from a three frequency signal input was more successful in defining the performance of the multiplexer during this test. The X-Y plots were obtained by using the plotter outputs of a spectrum analyzer. The spectral distribution of the signal complex at the input to the ULM-101 using three equal level signals as a composite power level of 0 dBm is shown on figure 31.

3.1.12.3.3 Figures 32 and 33 show the actual output spectrum of the ULM-101 for, respectively, channel rates of 8 kbps and 65 kbps and for a composite channel input level of 0 dBm. The signals at the three input frequencies are clearly visible in both figures. The intermodulation signals for the 8 kbps sampling rate are close to the ambient noise level which itself is relatively high with respect to the fundamental inputs. The intermodulation products for the 64 kbps sampling rate are more clearly defined. The third order product at 340 Hz especially strong for both sampling rates and the third order product at 2420 Hz is high at the 64 kbps sampling rate. Similar results were obtained for both CVSD and log CVSD code techniques.

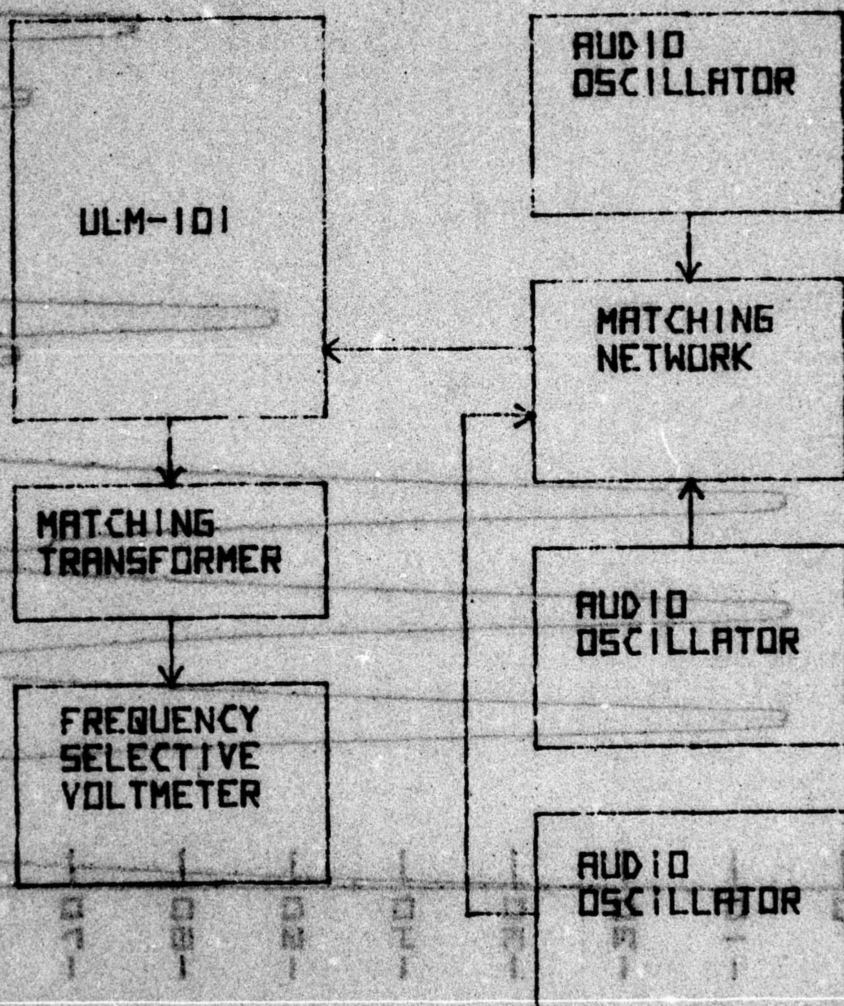


FIGURE 30. 3 FREQUENCY DISTORTION TEST CONFIGURATION

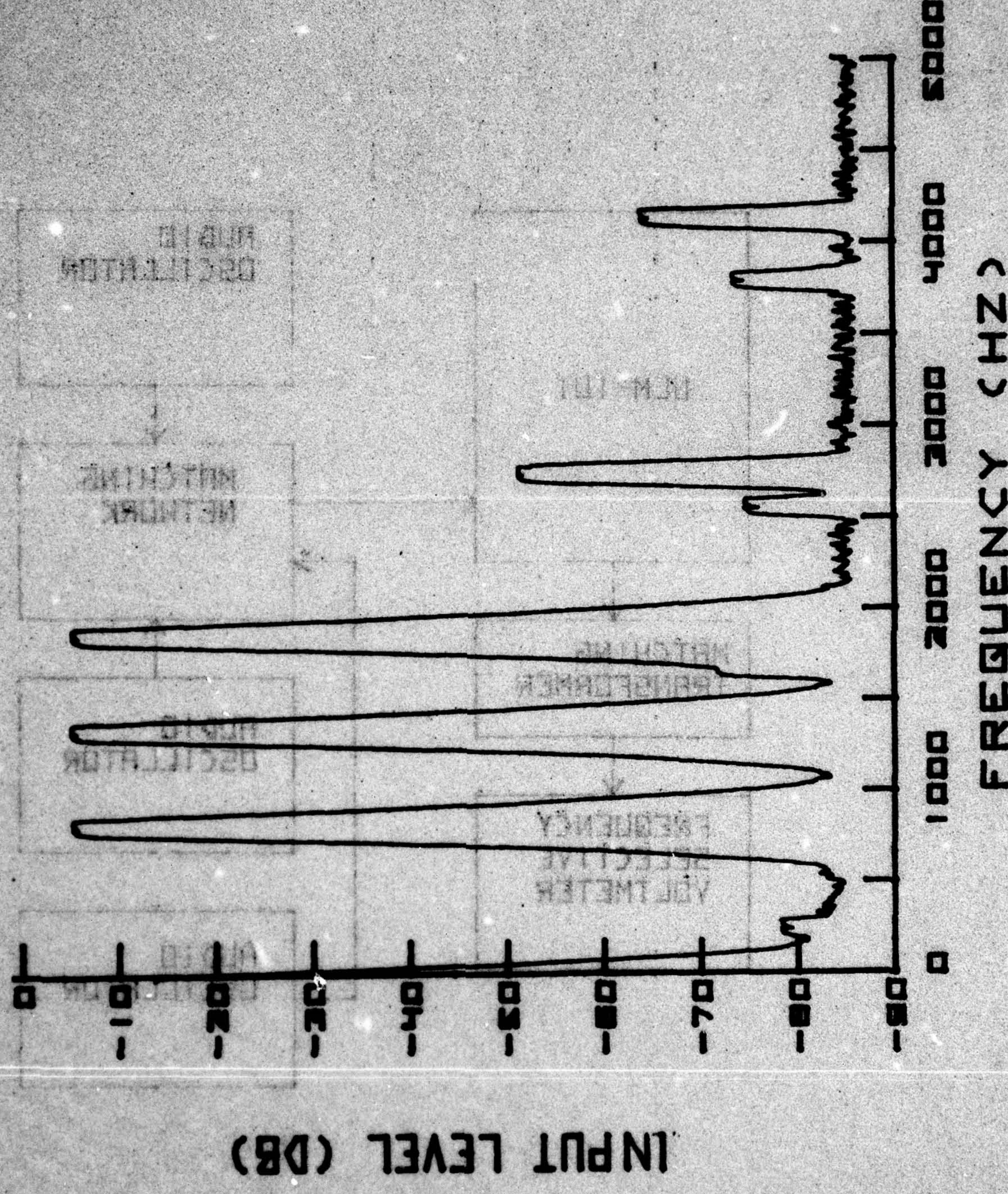


Figure 31.
Three Frequency Intermodulation Input Spectrum

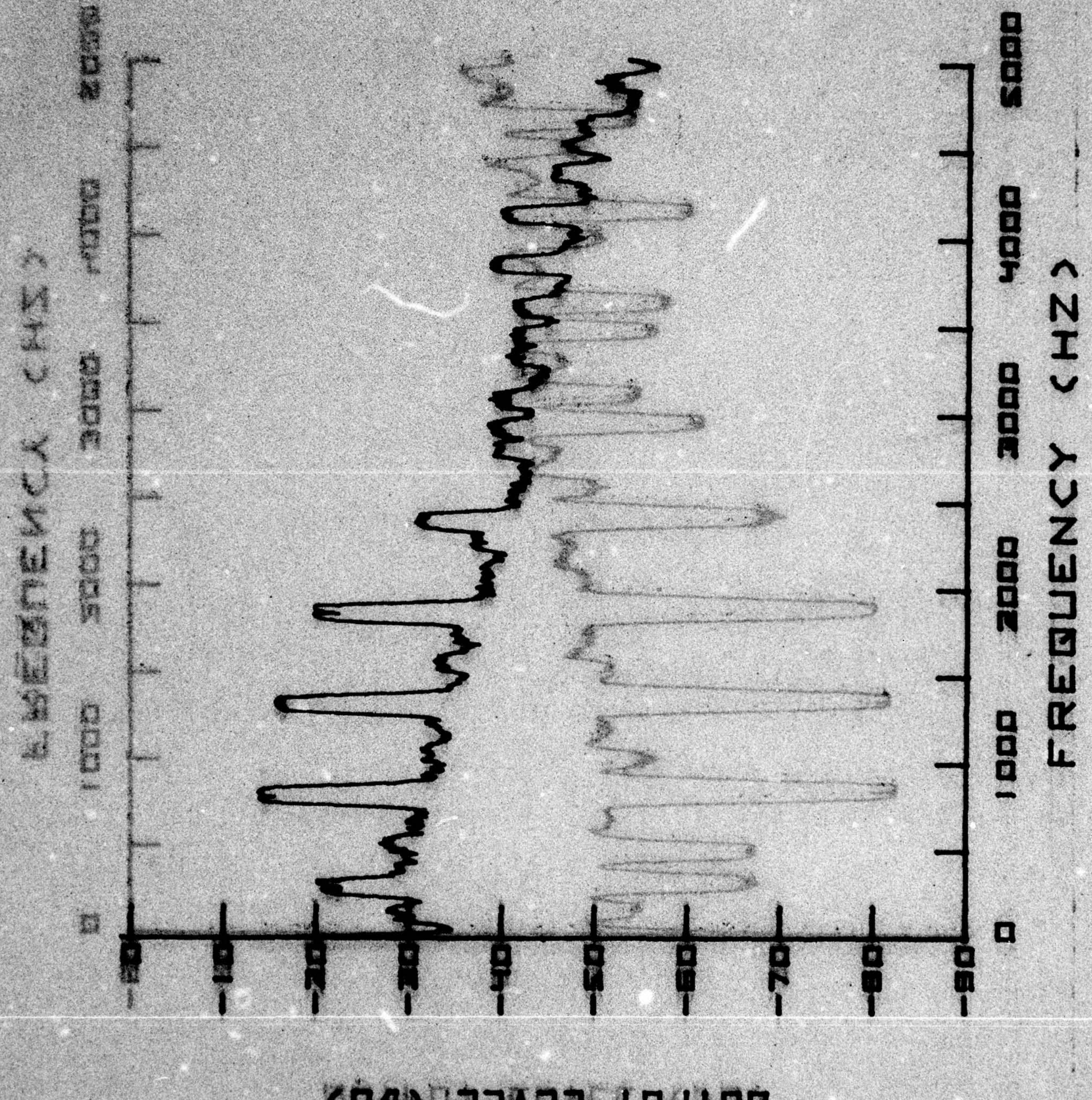


Figure 32.

Three Frequency Intermodulation Test Results

(8 kbps, 0 dBm)

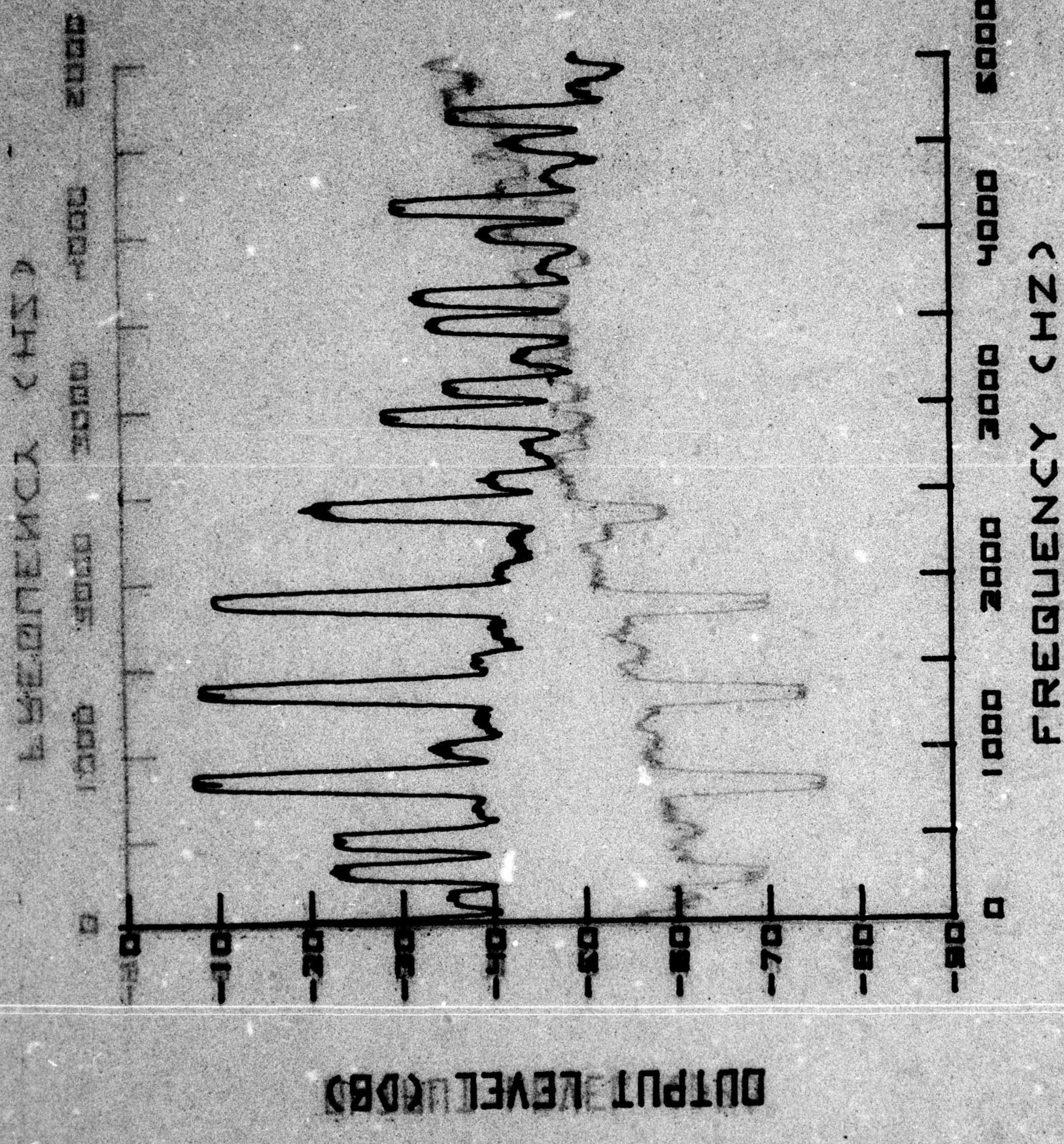


Figure 33.
Three Frequency Intermodulation Test Results
(64 kbps, 0 dBm)

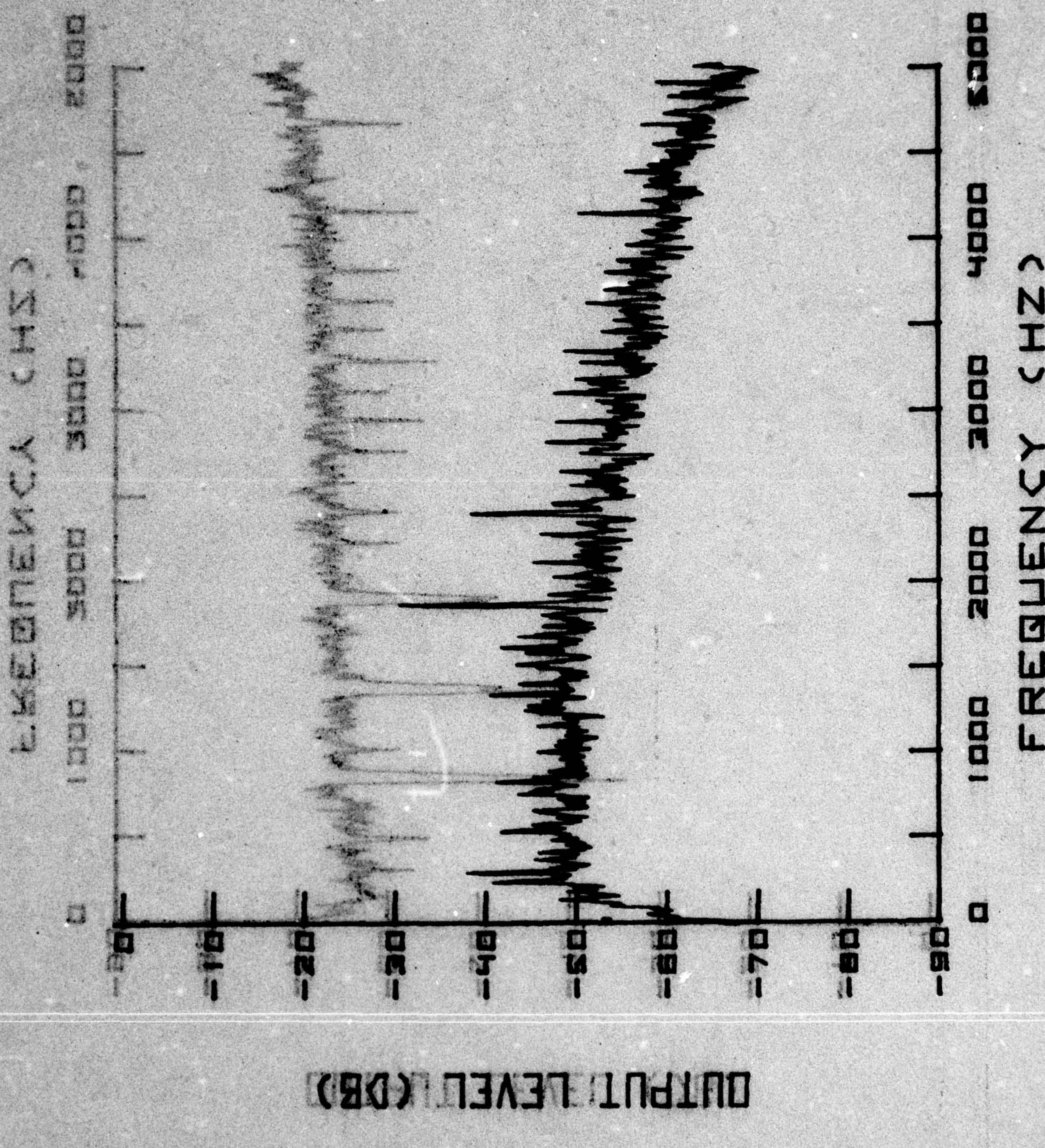


Figure 34.

Three Frequency Intermodulation Test Results

(8 kbps, -13 dBm)

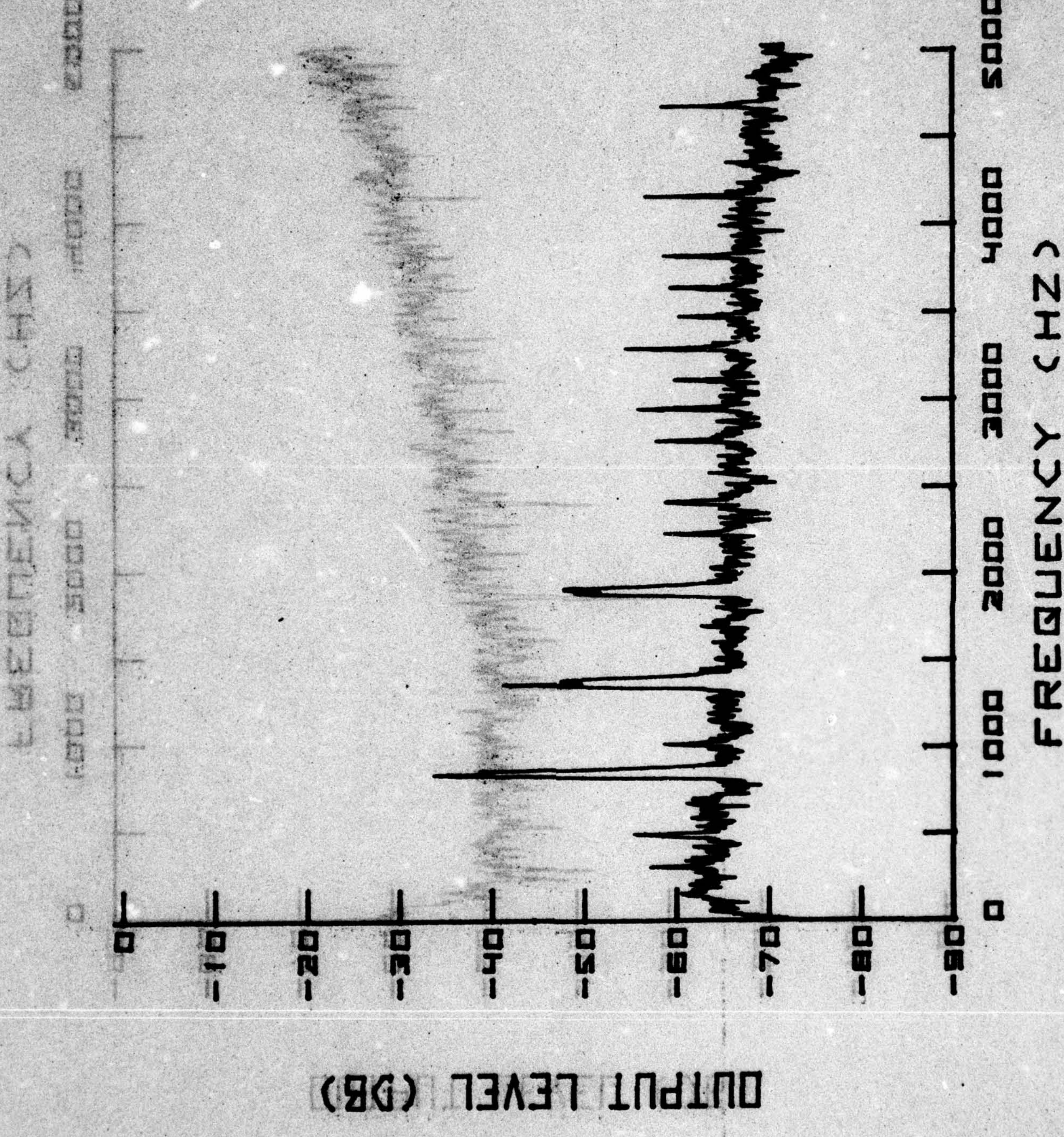


Figure 35.

Three Frequency Intermodulation Test Results

(64 kbps, -13 dBm)

3.1.12.3.4 Figures 34 and 35 show the output spectrum of the ULM-101 for, respectively, channel rates of 8 kbps and 64 kbps for a composite channel input level of -13 dBm. At 8 kbps sampling rate the results are virtually identical to those obtained with a 0 dBm composite channel input level. At a 64 kbps sampling rate the reduction in slope overload effects due to the reduction in input level results in a reduction in the level of the intermodulation products, particularly the product previously noted at 2420 Hz. Again similar results are obtained for both CVSD and log CVSD techniques.

3.1.12.3.5 The results of this test indicate that, for a multi-tone input to the ULM-101, a series of intermodulation products, as well as a few internally generated spurious tones, will be produced at levels which are significant with respect to the input tones.

3.2 QUASI-ANALOG SIGNAL TESTS

3.2.1 Voice Frequency Carrier Telegraph, AN/FCC-19 Test

3.2.1.1 Objective. The purpose of this test is to determine the ability of the ULM-101 to process a frequency complex from Voice Frequency Carrier Telegraph (VFCT) equipment without creating unacceptable performance degradation in the VFCT equipment.

3.2.1.2 Procedure.

3.2.1.2.1 The equipment configuration for this test is shown on figure 36. The Data-Tek 9600 was used to originate a test message and provide this message as a dry contact keyer to one channel of the AN/FCC-19. Fourteen of the remaining 15 channels of the AN/FCC-19 were looped together and loaded with the dotter (r-4) output of the AN/FCC-19. The remaining channel was inoperative. The output of the AN/FCC-19 channel under test was connected back to the Data-Tek 9600 to allow measurements of errors and distortion to be made on the signal. The multiplex output of the AN/FCC-19 was connected to a channel input of the ULM-101 and the corresponding channel output was connected to the multiplex input of the AN/FCC-19. The ULM-101 was looped on itself at the group level to provide the total loop.

3.2.1.2.2 The test was initially performed with the configuration of figure 34. The same test was performed again for increasing numbers at loopbacks of the ULM-101 as described in paragraphs 3.1.8 for the loop test.

3.2.1.2.3 The test was performed for both coding techniques and all four sampling rates of the ULM-101. The test was performed for AN/FCC-19 channel center frequencies of 425, 1275, and 2975 Hz. AN/FCC-19 was operating at 100 wpm.

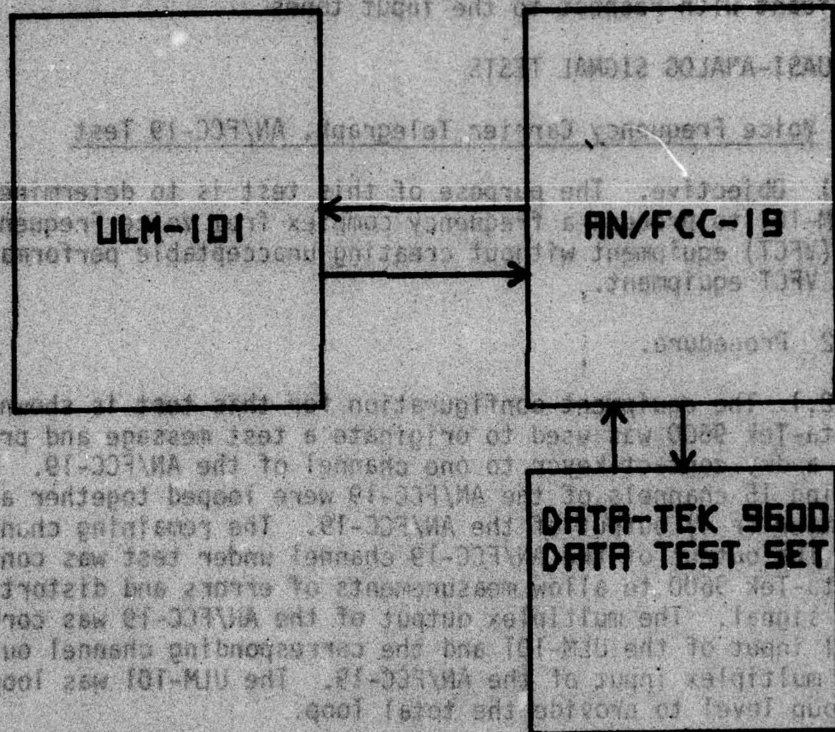


FIGURE 36. AN/FCC-19(VFCT) CONFIGURATION

TABLE IX. AN/FCC-19 Performance with ULM-101

CHANNEL CODE TECHNIQUE	CHANNEL RATE (KBPS)	AN/FCC-19 PERFORMANCE					
		425 Hz Cent Freq.		1275 Hz Center Freq.		2975 Hz Center Freq	
		Errors	Distortion (%)	Errors	Distortion (%)	Errors	Distortion (%)
CVSD	8	337	24	294	28	359	30
	16	91	22	57	20	101	28
	32	2	14	2	16	3	22
	64	1	10	0	14	0	16
LOG CVSD	8	380	24	267	24	345	29
	16	89	20	38	14	96	24
	32	2	14	1	14	5	20
	64	0	14	0	6	0	16

TABLE X. AN/FCC-19 Performance (ULM-101 Loop Backs)

CHANNEL RATE (KBPS)	NUMBER OF LOOPBACKS	AN/FCC-19 PERFORMANCE					
		425 Hz Cent Freq.		1275 Hz Center Freq.		2975 Hz Center Freq	
		Errors	Distortion (%)	Errors	Distortion (%)	Errors	Distortion (%)
32	0	2	14	2	16	3	22
	1	148	22	44	20	218	22
	2	186	22	78	21	359	28
	3	222	26	124	22	319	30
64	0	1	10	0	14	0	16
	1	88	22	22	18	128	22
	2	133	24	35	18	286	28
	3	217	24	54	19	375	30

3.2.1.3 Results and Analysis.

3.2.1.3.1 Table IX shows the results of the measurements made on the AN/FCC-19 for a single loop through the ULM-101. The error counts were accumulated over a two minute time period in each case.

3.2.1.3.2 It can be seen from a review of Table IX that approximately the same results were obtained for CVSD and log CVSD coding techniques. At 8 and 16 kbps sampling rates, the number of error was lower for a center frequency of 1275 than for either of the extremes of center frequency. The distortion generally increased with an increase in center frequency. At 32 and 64 kbps, the number of errors was approximately the same for all three center frequencies.

3.2.1.3.3 The results of this test show that the AN/FCC-19 would be unusable with the ULM-101 for sampling rates of 32 kbps and 64 kbps.

3.2.1.3.4 Table X shows the results of the measurements made on the AN/FCC-19 for successive number of loopbacks at channel level through the ULM-101. Only sampling rates of 32 and 64 kbps are shown since sampling rates of 8 and 16 kbps result in maximum readings of errors and distoriton. Similar results were obtained for DVSD and log CVSD coding techniques so only the CVSD coding results are shown. At four loopbacks through the ULM-101 the AN/FCC-19 ceased to function for any sampling rate.

3.2.1.3.5 As can be seen from a review of Table X, the number of errors and amount of distortion increases with increasing numbers of loopbacks. The number of errors observed using the 1275 Hz center frequency channel are consistently smaller than either of the center frequency extremes.

3.2.1.3.6 The results of Table X indicate that even one loopback at channel level of the ULM-101 results in an increase in errors and distortion which would result in unusable operation of the AN/FCC-19 in most cases. It is possible that, using a center frequency of 1275 Hz and a ULM-101 sampling rate of 64 kbps, message traffic ould be passed but it would be of extremely marginal quality.

3.2.2 <u>SF Signaling Test</u>.

3.2.2.1 Objective. The purpose of this test is to determine the ability of the ULM-101 to pass SF signaling at vaiours pulse rates and input levels.

3.2.2.2 Procedure.

3.2.2.2.1 The equipment configuration for this test is shown in figure 37. The Northeast Electronics TTS-26B pulse signaling test set and TTS-26BXS-1 Signaling Circuit Panel were used to originate a SF signal at pulse rates of 6, 8, 10, 12, 14, and 20 pps and at levels of -13, -16, -20, and -24 dBm. The carrier frequency was also varied between 1, 1.6, 2.4, and 2.6 kHz. The percent break of the transmitted signal was set to 67 percent. The percent break of the received signal from the ULM-101 was measured with the TTS-26B and recorded.

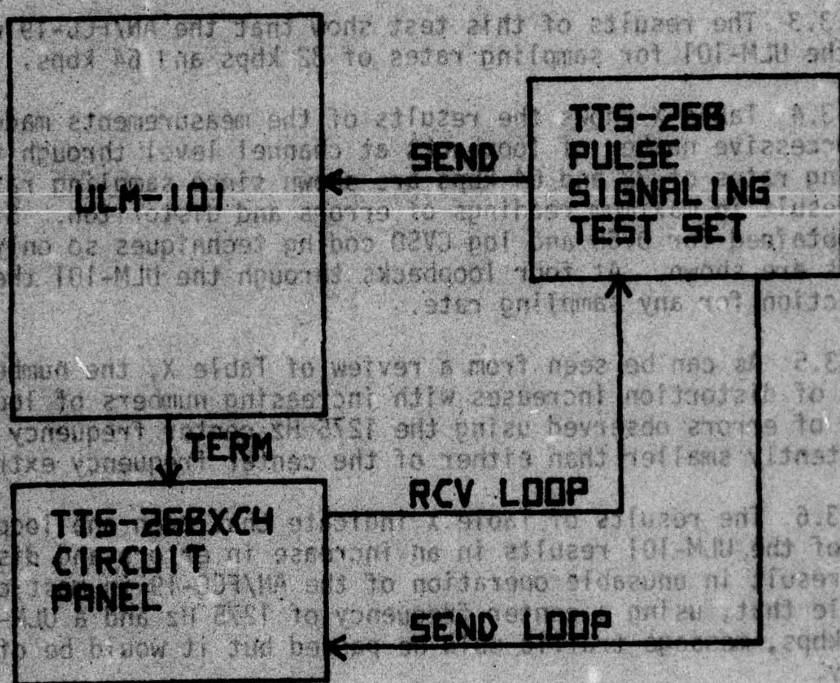


FIGURE 37. SF SIGNALING TEST CONFIGURATION

TABLE XI. Part I SF Signaling Test Summary

INPUT LEVEL (dBm)	ULM-101 SAMPLE RATE (KBPS)	1 KHz Oscillator						1.6 KHz Oscillator					
		6	8	10	12	14	20	6	8	10	12	14	20
-13	8	95	100	100	100	100	100	94	100	100	100	100	100
	16	100	100	95	100	100	98	100	100	100	100	100	100
	32	74	76	77	81	82	90	75	80	82	87	88	96
	64	67	67	67	67	68	69	68	69	71	71	70	74
-16	8	92	100	100	100	100	100	90	100	100	100	100	100
	16	100	98	100	100	100	100	100	100	95	100	100	100
	32	70	80	78	81	82	90	75	78	80	88	88	92
	64	68	67	70	72	79	70	68	69	69	75	70	74
-20	8	97	100	100	100	100	100	95	100	100	100	100	100
	16	80	66	68	80	75	71	70	75	75	77	72	74
	32	77	78	80	85	85	95	75	78	82	85	88	97
	64	67	67	67	68	68	71	67	70	71	72	74	77
-24	8	100	100	100	100	100	100	100	100	100	100	100	100
	16	100	100	100	100	100	100	100	97	88	100	95	100
	32	72	72	75	76	80	85	76	75	78	80	85	90
	64	68	65	67	70	68	71	69	68	67	69	69	74

TABLE XI. Part II SF Signaling Test Summary

INPUT LEVEL (dBm)	ULM-101 SAMPLE RATE (KBPS)	2.4 KHz Oscillator						2.6 KHz Oscillator					
		6	8	10	12	14	20	6	8	10	12	14	20
-13	8	10	5	25	20	20	25	15	25	15	22	30	35
	16	67	67	67	67	67	69	100	100	100	100	100	100
	32	75	77	80	82	86	94	86	78	84	85	90	97
	64	69	70	72	74	75	78	70	70	74	72	75	79
-16	8	5	0	25	10	10	20	5	15	20	20	15	10
	16	66	67	67	72	67	69	100	100	100	74	100	100
	32	75	78	80	96	85	95	75	77	81	88	87	96
	64	69	70	71	77	74	76	69	71	71	76	74	77
-20	8	5	10	20	25	15	20	5	10	15	20	20	20
	16	68	67	68	67	69	73	100	100	100	100	100	100
	32	70	71	72	73	77	81	77	81	84	88	94	100
	64	70	72	73	74	76	80	70	72	74	75	76	83
-24	8	100	10	0	20	10	15	5	15	15	35	20	20
	16	75	98	100	100	100	100	97	95	100	95	100	100
	32	68	75	79	85	87	96	76	76	80	84	85	96
	64	5	68	68	71	70	75	69	68	68	74	70	75

3.2.2.2.2 The test was performed for both coding techniques and all four sampling rates of the ULM-101.

3.2.2.3 Results and Analysis.

3.2.2.3.1 Table XI shows the results of the SF signaling test for a log CVSD coding technique. Similar results were obtained for CVSD coding technique. The table shows that an ULM-101 sampling rate of 8 kbps resulted in an unacceptable signal for any input level, oscillator frequency, or pulsing rate. The 16 kbps sampling rate provided a useable signal at a few combinations of input level, oscillator frequency and pulsing rate but was generally also unuseable. The 32 kbps sampling rate, while providing more consistent results than either of the lower sampling rates, generally provided unacceptable signaling results. Only at a 64 kbps sampling rate did the ULM-101 provide signaling which might be useful in a commercial installation, and even this rate provided a few marginal results.

3.2.2.3.2 An overall review of the SF signaling test of the ULM-101 leads to the conclusion that the ULM-101 is unsatisfactory as a medium for transmitting SF signaling information. Preliminary data from a signaling test involving repeated loopbacks of the ULM-101 reveals that after two loopbacks, even the 64 kbps sampling rate yields unacceptable signaling information.

3.2.3 <u>MF Signaling Test</u>

3.2.3.1 Objective. The purpose of this test is to determine the ability of the ULM-101 to pass MF signaling combination accurately.

3.2.3.2 Procedure.

3.2.3.2.1 The equipment configuration for this test is shown on figure 38. The TTS-59B was used to originate a seven digit number which was transmitted via the ULM-101 to the TTS-2761 when the received frequency combination was detected, decoded and the number displayed. The TTS-59B transmitted the MF combinations at a level of -22 dBm.

3.2.3.2.2 The test was initially performed with the configuration of figure 38. The test was repeated for increasing number of loopbacks of the ULM-101 as described in paragraph 3.1.8 for the loop test.

3.2.3.2.3 The test was performed for both coding techniques and all four sampling rates of the ULM-101. The digits of the TTS-59B selector for each test run were varied so that all ten digits were used. Two measurements were made at each sampling rate.

3.2.3.3 Results and Analysis.

3.2.3.3.1 Table XII shows the results of the test of MF signaling combinations with the ULM-101. For a single transit through the ULM-101, only the 8 kbps

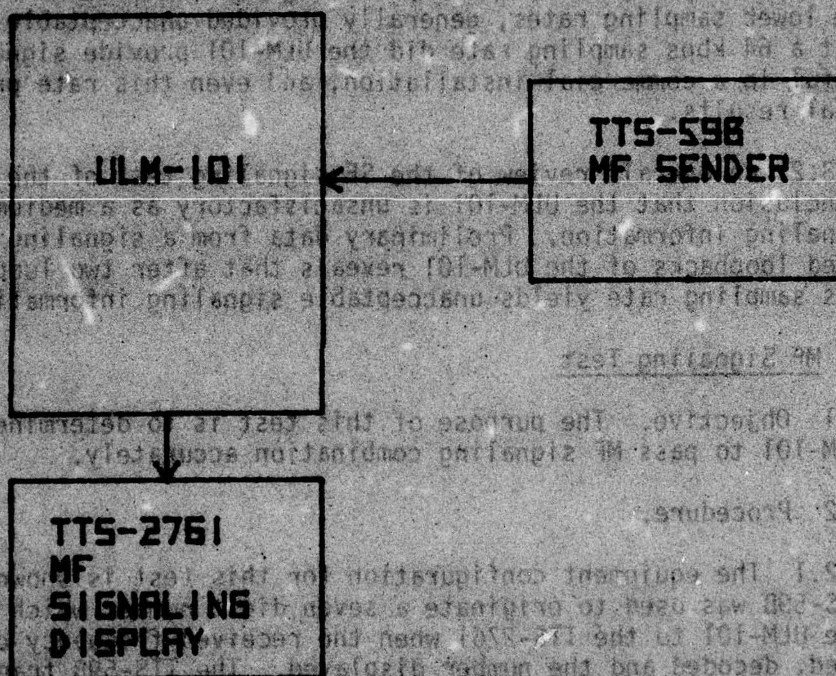


FIGURE 38. MF SIGNALING TEST CONFIGURATION

TABLE XII. MF SIGNALLING TEST SUMMARY

Number of Loopbacks	Code Technique	Channel Rate (KBPS)	Number of Errors	
			1st Attempt	2d Attempt
0	CVSD	8	1	0
		16	0	0
		32	0	0
		64	0	0
	LOG CVSD	8	3	1
		16	0	0
		32	0	0
		64	0	0
1	CVSD	8	6	5
		16	4	1
		32	0	0
		64	1	1
	LOG CVSD	8	4	5
		16	1	1
		32	2	0
		64	0	0
2	CVSD	8	4	6
		16	2	1
		32	2	2
		64	1	0
	LOG CVSD	8	5	3
		16	1	1
		32	3	2
		64	3	1
3	CVSD	8	6	5
		16	4	3
		32	3	1
		64	4	1
	LOG CVSD	8	6	4
		16	3	3
		32	3	3
		64	1	4

sampling rate provided an erroneous digit; at other sampling rates the dialing information was correctly transmitted. As the MF signal was looped-back through the ULM-101, errors were introduced in the dialing information at all sampling rates.

3.2.3.3.2 When errors occurred in the transmission of digits, the indication on the signaling display was that more than two tones had been received (the signaling is based on pairs of tones from the basic six tones available). When a wrong number was decoded, the cause was probably the detection circuits of the signaling using an erroneous tone in its decision of what number was transmitted. The erroneous tones are created by intermodulation of the two basic tones and by internally generated spurious signals. Repeated loopbacks through the ULM-101 strengthen those unwanted tones.

3.2.3.3.3 The use of the ULM-101 for the transmission of MF signaling combinations is questionable. Normal noise encountered in a switching network would probably be sufficient to create errors in the transmission of signaling information when passed through the ULM-101.

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